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OLDMAN RIVER DAM
RESERVOIR RELATED WORKS

OLDMAN RIVER DAM
RESERVOIR RELATED WORKS
PRELIMINARY ENGINEERING REPORT

Part 2 of 5
CPR and Highway 3 Bridges
Geotechnical Investigations and Structural Protection Measures

July 1987

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21 July 1987
File: 71-84-1-1

LETTER OF TRANSMITTAL

Alberta Environment
Oldman River Dam Project Office
Main Floor, Oxbridge Place
9820 - 106 Street
EDMONTON, Alberta
T5K 2J6

Attention: **R. N. McManus, P. Eng.**
Project Manager

Reference: **Oldman River Dam/Reservoir Related Works**
Preliminary Engineering Report
Part 2 of 5 - CPR and Highway 3 Bridges over Castle River
Geotechnical Investigations and
Structural Protection Measures

Gentlemen:

Stanley Associates is pleased to submit this Part 2 Preliminary Report document. It deals with structural protection measures and describes the geotechnical investigations undertaken pertinent to the Reservoir Related Works associated with the Oldman River Dam.

The report is intended to provide a basis for discussions between Alberta Environment and CP Rail concerning their bridge, and between Alberta Environment and Alberta Transportation concerning the Highway 3 Bridge crossing Castle River. It also provides extensive geotechnical data and recommendations concerning the CP Rail bridge, for use in the predesign and design phases of implementation, subsequent to decisions being reached by Alberta Environment.

This report was prepared within the context of the overall Preliminary Study program, however "stands alone" in dealing with the issues pertinent to these two structures. Thus the text of this report contains a summarization of some of the basic reservoir operation consideration; a description of the various alternatives assessed as the study progressed; the geotechnical design recommendations for each bridge and a description of the preferred options and their costs. The report also contains two annexed subsidiary reports. The first describes the detailed geotechnical program undertaken at the CPR crossing location and develops the geotechnical design recommendations, while the second documents the preliminary geotechnical recommendations for protecting the Highway 3 bridge.

...cont'd...

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Cost estimates for protective measures related to creation of the reservoir are as follows:

CP Rail Bridge Protection, Approach Modifications and River Channelization	$20,500,000
Highway 3 Bridge Slope Stabilization and River Channelization	$ 5,800,000

These costs are expressed in 1986 dollars and are additive to the costs presented in the Part 1 Report. An alternative approach may have some appeal to CP Rail. If they are prepared to contribute financially, and are able to cooperate in scheduling appropriate (brief) periods of rail closure, a virtual replacement of the entire structure in situ is believed to be practical. This option is also briefly described for discussion between Alberta Environment and CP Rail.

A tentative schedule for predesign, design and construction of works at these two structures is included in Section 4.

We have particularly enjoyed working on these aspects of the project and look forward to continuing to assist Alberta Environment in meetings with owners of these two structures and in proceeding with the next stages of design.

Yours very truly,

STANLEY ASSOCIATES ENGINEERING LTD.

K. A. Hamman, P.Eng.
Project Coordinator

KAH/plg
Encl.

OLDMAN RIVER DAM
RESERVOIR RELATED WORKS
- PRELIMINARY ENGINEERING STUDY -

This document is Part 2 of a series of five preliminary engineering reports. The five reports are separately bound documents titled as follows:

Part 1 of 5

Transportation System Modifications,
Utilities and Reservoir Clearing

Part 2 of 5

C.P.R. and Highway 3 Bridges
Geotechnical Investigations and Structural Protection Measures

Part 3 of 5

Reservoir Boundary Study

Part 4 of 5

Reservoir Hydrogeology Study and
Groundwater Monitoring Program

Part 5 of 5

Test Hole Logs

LIST OF FIGURES

OLDMAN RIVER DAM
RESERVOIR RELATED WORKS

PART 2 OF 5

CPR AND HIGHWAY 3 BRIDGES
GEOTECHNICAL INVESTIGATIONS AND
STRUCTURAL PROTECTION MEASURES

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SECTION 1
INTRODUCTION

1.1 GENERAL

This report, constitutes Part 2 of a 5 part preliminary report on the study of implications arising from construction of the Oldman River Dam Reservoir. It addresses the CP Rail crossing of the Castle River in W½13-7-1-W5 and the Highway 3 crossing in the SE¼11-7-1-W5 and SW¼12-7-1-W5, 2 km further upstream. These crossing locations are identified on Drawing 1.1 following. Comprehensive regional geology, reservoir stability and other infrastructure impacts are dealt with in the other study documents. In order that this document can largely stand alone as a basis for discussions with CP Rail and Alberta Transportation, some items of specific relevance to these crossings are repeated here, and, importantly, specific geotechnical investigations and recommendations pertaining to these existing alignments are provided in this document.

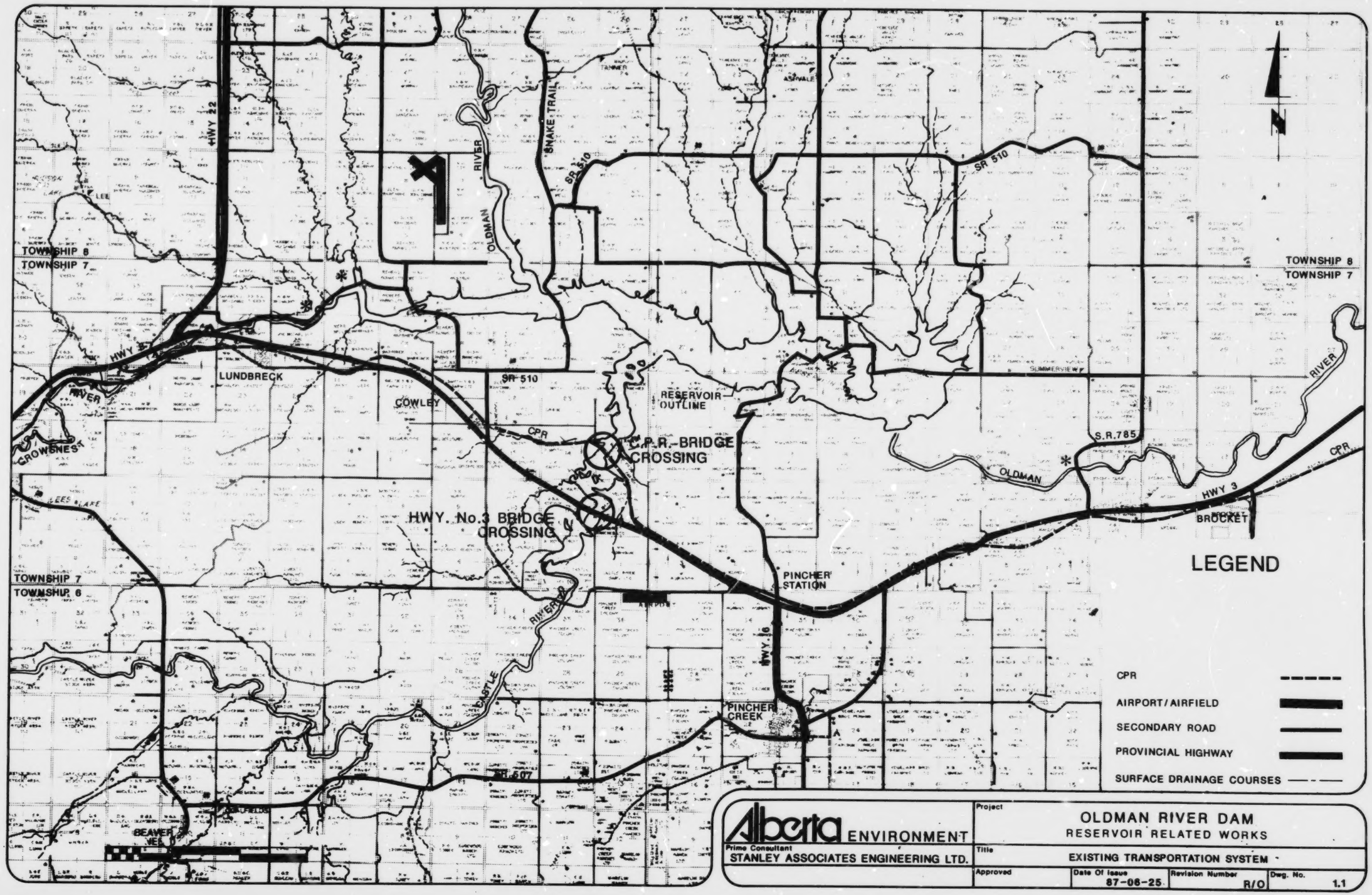
1.2 BACKGROUND

In August of 1984, the Alberta Government announced a decision to undertake studies and pursue construction of a dam on the Oldman River. The selected dam site is approximately 10 km downstream of the confluence of the Oldman River with the Crowsnest River and 8 kilometers downstream of the confluence with the Castle River.

Operation of the dam will create a reservoir with upper limits on the Castle River about two km upstream of the Highway 3 bridge.

1.3 CONSULTANT ASSIGNMENTS

Two consultant assignments were issued by Alberta Environment; one to a joint venture of UMA/Acres as Prime Consultants for a Dam Related Package, and a Reservoir Related Works Package to Stanley Associates Engineering Ltd. The assessment of the impact of creating the reservoir on these two existing structures falls within the latter package. Klohn Leonoff Ltd. was retained by Stanley Associates to undertake reservoir related geotechnical studies and to make recommendations concerning foundations at these particular sites.



Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.

Project: OLDMAN RIVER DAM
RESERVOIR RELATED WORKS

Title: EXISTING TRANSPORTATION SYSTEM

Approved	Date Of Issue	Revision Number	Dwg. No.
	87-08-25	R/O	1.1

1.4 STUDY APPROACH

The engineering approach that has guided the study has been to protect existing facilities where practical, unless replacement is less costly. Where replacement has been considered, it has contemplated provision of equivalent levels of service to those currently existing.

1.5 RESERVOIR OPERATION CONSIDERATIONS

Alberta Environment will be responsible for operation of the dam. Several aspects of operation are significant to the two structures in question.

1. The reservoir full supply level (FSL) determines the normal high water elevation of the reservoir. It has been set at elevation 1118.6 m (geodetic).

2. The minimum reservoir operating level has been set at elevation 1064 m, which is below the riverbed elevation at the CPR crossing. Thus reservoir drawdown to elevations below the existing riverbed will potentially occur at these structures annually in the future. When the reservoir is lowered faster than the adjacent saturated soil and rock in the valley walls are able to drain, this will result in residual pore water pressures, and consequent reduced rock and soil strengths. Potential failure planes in the rock and soil structures can develop more readily in this condition than in the case where excess porewater pressures are not present. This is an important consideration in ensuring stability of the abutment slopes at both bridge sites, requiring installation of free-draining, protective berms.

3. It is also possible that design floods will need to be accommodated in the modified low water channel that will exist in the future at both the CPR and Highway 3 crossings.

4. Since reservoir levels will fluctuate between the FSL elevation and the minimum operating level, shorelines at various elevations will be subject to wave and ice action. This is a determinant for protective armoring of the banks at these structures.

   Since it is anticipated that the channel section will be altered by abutment stabilization works, the affect of flood flows in the new channel needs to be assessed.

5. Alberta Environment has advised that the maximum winter operation elevation will be 1110.0 m geodetic. This, therefore, is the elevation assumed for application of both thermal and impact ice forces at these structures.

6. Alberta Environment proposes to commence reservoir filling in the Fall of 1990. Although the reservoir will not likely be filled to FSL in the first year, preliminary scheduling has targeted completion for construction of all Reservoir Related Works for the Fall of 1990.

These various operating assumptions were taken into account during development of the technical recommendations of this study.

SECTION 2
CP RAIL BRIDGE

2.1 GENERAL

An existing CP Rail bridge carries a single track on the Crowsnest Pass rail line across the Castle River Valley west of the Town of Pincher Creek, at CPR Mile 65.6. The bridge location in W½13-7-1-W5 is illustrated on Drawing 1.1. This location is within the area that will form a part of the Oldman River Dam Reservoir. Although prefeasibility level studies in the 1960's had originally anticipated the need to rebuild the crossing, detailed topography and dam operation plans now indicate a lesser impact at this location than had earlier been contemplated. Thus, primary effort in this study has been directed at developing systems to protect the existing structure.

2.2 EXISTING STRUCTURE AND APPROACHES

The bridge is 288 meters between abutments, supported on fourteen steel bents. Bents 1 and 14, adjacent to the east and west abutments respectively, are single bents. The other bents are in cross-braced pairs creating space trusses. The superstructure members are comprised of two built-up plate girders approximately 2.1 m deep. They are simply supported spans alternating between 22.9 m and 13.7 m with 22.9 m spans at both abutments. The bents of the steel space trusses are supported on reinforced concrete pedestals approximately 6 m high. The foundation of the other two steel bents and the abutments are concrete. The "as-built" drawings show that the concrete pedestal pads are founded on or within bedrock. The base of rail elevation is approximately elevation 1137 meters, some 40 meters above the river valley elevation.

The track borders a coulee for a distance of about 900 m east of the bridge. Slope movements along the coulee have resulted in the need for regular maintenance. On the west side of the bridge the track has been constructed along the north facing side of another coulee. Again, past slope movements have resulted in various remedial works including piling, berms and subsurface drains.

Protection of the existing bridge and the approaches needs to be based on the new external forces that will be applied to the bridge and its foundation as a result of flooding

the Reservoir. Protection will be needed for stabilization of the abutments to counter potential instability due to reservoir drawdown effects. Protection will also be needed to ensure that the design flood flows are safely passed through the modified channel at this location.

These factors are addressed in this preliminary study under three headings:

- Geotechnical Assessments and Recommendations
- River Engineering Assessment, and
- Structural Alternatives.

Composite cost estimates for making the recommended provisions follow.

2.3 GEOTECHNICAL ASSESSMENTS AND RECOMMENDATIONS

A comprehensive report on the geotechnical investigations and recommended remedial work is bound into this report as Annex A. The conclusions and recommendations from this annexed document are repeated below.

2.3.1 Conclusions

1. The bedrock underlying the CPR bridge site belongs to the Willow Creek Formation. It dips at 7° to the N75°E on the west side of the river and at 7° to the N48°E on the east side of the river. Along the longitudinal axis of the bridge, the bedrock dip is at 3° towards the river on the west side and horizontal on the east side. Relatively weaker seams or shear zones exist parallel to the bedrock close to the toe of the slope under both abutments. The material within the shear zones is considered to have a strength equivalent to a residual effective friction angle ϕ'_r of 15°, with zero cohesion.

2. Both abutments require buttressing fills to provide an adequate factor-of-safety for slope stability during rapid reservoir drawdown.

3. New pier foundations in the valley bottom with minimum horizontal dimensions of 5 m, will be stable under the calculated ice forces. Temporary support or

underpinning of the existing pier foundations may be required during construction depending on the condition of the rock at each footing.

4. Excavations around existing pier foundations on the valley slopes will require temporary support to prevent movement of the existing foundations while the larger new foundations are under construction.

5. The coulees to the west and east of the bridge presently show signs of instability due to high groundwater levels and blockage of drainage by track fills. Rapid drawdown of the reservoir would decrease the stability of the toes of the slopes and so stabilizing berms are recommended. These berms will not stabilize the overall slope but will only stabilize that portion of the slope affected by the reservoir.

2.3.2 Recommendations

Bridge Abutment Stability

The stability analysis for rapid drawdown for the two abutments indicated factors-of-safety of 0.8 and 0.9 for the west and east abutments respectively. Therefore, stabilizing berms are needed to raise the factor-of-safety to a recommended 1.35. The recommended design is a composite slope of 3.5H:1V as shown in section and plan on Drawing No. 2062.102 (Annex A). The results of the stability analysis for the berm design at the two abutments is presented on Drawing Nos. 2062.103 and .104 (Annex A).

The berm fill must be free draining gravel to meet the assumptions made in the stability analysis. It should be placed in lifts not exceeding 400 mm and compacted to a density of 97% Standard Proctor.

The berms must be protected from erosion. Details of the riprap design are presented on Drawing No. 2062.102 (Annex A).

Due to the restriction of the valley width caused by the berms, the lower portion of the valley will be subjected to high flow velocities at low water levels. Therefore, the heavy riprap design (Type A) is required below elevation 1102 and across the river valley as

shown on Drawing No. 2062.102 (Annex A). The light riprap design (Type C) may be used above elevation 1102 to the top of the berm. The specifications for the riprap and Type C bedding are as follows:

GRADATION OF RIPRAP

TYPE A (kg)*			TYPE C (kg)*		
W_{80}	$\geqq$	1200	W_{80}	$\geqq$	150
W_{50}	$\geqq$	700	W_{50}	$\geqq$	50
W_{20}	$\geqq$	180	W_{20}	$\geqq$	10

*Note: Type A is equivalent to Class III and Type C is equivalent to Class I. These Classes refer to equivalent diameters as referenced elsewhere in the Preliminary Report series.

GRADATION OF BEDDING

Sieve Size	Range of Grading by % Passing
400	100
300	100-80
200	85-60
100	55-30
50	30-0
20	15-0

A layer of geotextile should be placed beneath the riprap.

During detailed design, consideration of equivalent concrete alternatives should be assessed.

Support of Piers

A review of the pier foundations was made for bearing and potential for sliding on weak shear planes in the bedrock. An allowable bearing capacity of 500 kPa is recommended for footings founded in the Willow Creek Formation at the existing riverbed elevations.

A check was made of the footing resistance to sliding due to horizontal forces. A weak bedding plane was assumed near the base of the footing and a $K_o = 1$ for passive resistance was used. The calculated factor-of-safety is in excess of 1.5 providing the footing has minimum base dimensions of 5 m x 5 m.
It is assumed that all piers will be founded in bedrock. Prior to placement of concrete the bedrock surface must be cleaned of all loose rock and debris. Careful use of compressed air will achieve the best results.

If the rock adjacent to the existing footings is badly disturbed it may be necessary to deepen the excavation beside the footing. However, existing footing support must not be disturbed and special anchors through the footings may be required. Information on the bedrock should be gathered prior to construction in order to determine the elevation for the base of each footing excavation and the best means of ensuring the existing footing support is not disturbed.

Pier Stabilization

A special problem will exist for construction of the piers on the west and east valley slopes. Since larger piers will require excavation of the rock on the slope, potential undermining of existing pier support could occur. A staged system of excavation and anchoring is thus recommended as shown on Drawing No. 2062.105 (Annex A). This drawing shows the proposed sequence of work for bents 12 and 13 on the west valley slope. A similar support system will be needed for bent 2 on the east valley slope.

Prior to commencement of excavation the bents should be drilled and anchored to the slope as shown on Drawing No. 2062.106 (Annex A).

As shown on Drawing No. 2062.107 (Annex A) each excavation stage should be no more than 2 m in height and reduced to 1 m if the rock strength indicates necessary. The excavation face should be shotcreted as soon as possible after excavation to prevent deterioration of the rock.

All rock anchors should be 10 m long and inclined 15° downward from the horizontal. Placement of the anchors should be staggered as shown on Drawing No. 2062.107 (Annex A) and a 500 mm square concrete anchor head should be cast-in-place after each

anchor is seated. After the concrete anchor head has cured, the anchor should be post-tensioned. Placement of anchor heads and tensioning of anchors should be undertaken as soon as possible after installation of the rock anchors and prior to commencement of excavation of the next stage. The effect of the post-tensioning should be to balance the horizontal earth pressure (active condition, K_A) including the component from the existing footing loads.

Excavation, foundation construction and backfilling should be synchronized. For example, on the west abutment, excavation of stages 8 to 12 should not be undertaken until construction of the foundation and backfill operations below the elevation of the upper bent (13) have been completed.

West Coulee Stabilization

The west approach to the bridge, has been constructed along the north facing side of a coulee. Since construction, the cut-fill slope has been unstable, and several failures have occurred. Various remedial measures have been attempted including a timber pile retaining wall, a drainage system, moving the trackbed into the slope, and flattening the backslopes above the track.

Based on observations and assessments of this study, it is considered that the cause of past and present slope failures at this location is groundwater blockage by the track fill and infiltration of runoff into the slope. It is believed that the failure surfaces are either within the soil layers, or tangent to bedrock. A similar conclusion has been arrived at in previous reports by others, however, CP Rail's efforts to correct the problems have not been fully effective to date.

Saturation of the toe of this slope by the reservoir and subsequent drawdown could create instability of the toe and result in a progressive slide. The instability would be amplified by the present metastable condition of the slope. Therefore, it is necessary to prevent movement of the toe by construction of a berm extending to FSL. For preliminary design, the berm should have a minimum slope of 3.5H:1V with a minimum top width of 6 m at FSL as shown on Drawing No. 2062.108 (Annex A). Because the present slope varies in gradient and alignment, some adjustments in the berm slope gradient may be required particularly at local, presently unstable areas where slump debris has collected at the toe

of slope. As the recommended berm will reach the other side of the coulee at many locations, it will be necessary to ensure ponding of surface drainage does not occur between the toe of berm and coulee slope. Additional filling and/or installation of a culvert may be necessary to achieve a uniform ditch gradient along the coulee bottom and to ensure positive drainage.

The surface of the berm should be protected by a layer of light riprap (Type C) and geotextile as recommended above. A layer of geotextile should be placed below the riprap.

It is emphasized that the toe berm will not prevent continued instability of the portion of the slope above FSL. This portion requires further drainage control to lower the high water table in the slope and excavation to reduce slope gradients. It was not in our terms of reference to stabilize the overall CPR track but only to stabilize that portion of the track affected by the reservoir. This matter should be dealt with by CP Rail.

East Coulee Stabilization

Approximately 900 m east of the bridge crossing, the track approaches a large coulee to the south of the track. At its closest point the track crosses a small tributary gulley. Originally the track crossed the gulley on a small bridge. This bridge was replaced by a fill and culvert in about 1985 or 1986. Similar to the west coulee, instability of the slope on the east coulee approach is also due to groundwater blockage by the track fill.

The reservoir will approach the toe of the slope in this area of present instability. Saturation of the toe by the reservoir and subsequent drawdown will have minor impact except that the slope is believed to be very close to a factor-of-safety of 1 and any toe movement could impact the overall slope. Therefore, a small fill is recommended in the coulee bottom as shown on Drawing No. 2062.108 (Annex A). Natural flow in the coulee should be channelled in a ditch on top of the fill and the downslope edge of the fill should be protected from erosion by Type C riprap. A culvert may also be considered during detailed design to ensure positive drainage is provided. This berm will not stabilize the overall slope but will eliminate the potential impact of the reservoir. CP Rail should take additional steps to resolve the existing instability problems.

2.4 RIVER ENGINEERING ASSESSMENT

2.4.1 Existing Channel Morphology

The Castle River in the vicinity of the CF Rail bridge crossing is entrenched in a 50 to 60 m deep stream-cut valley. A single channel within this valley is approximately 50 to 60 m wide and has an average slope in the order of about 0.37 percent. The channel pattern is irregular and partly confined, with large mid-channel and diagonal bars and occasional rock outcrops along the bed resulting in pool and ripple type flow at low water. The bed material underlying the bedrock is mainly coarse gravel with a median grain size of about 80 mm. The channel bank materials range from gravels and cobbles to bedrock. The overbank areas along the relatively narrow and fragmentary valley flat are vegetated with grasses and small shrubs.

Being entrenched, the present river channel location is relatively stable. Gradual erosion of the confining high terraces and/or valley walls appears to be the most active channel process. Steep cliffs are present wherever the river impinges on the valley walls and then turns abruptly.

At the CPR bridge crossing, about 5 km upstream of the confluence of the Castle River with the Oldman River, the river flows northeastward along the toe of the west valley slope at an elevation of about 1093.5 m (low water). The floodplain area immediately east of the main channel is approximately 100 m wide and lies at elevations ranging from about 1095 to 1097 m.

The 1 in 100 year flood has been calculated as 1040 m^3/sec (see Appendix C of Part 1 Report). Calculations indicate that the natural 1 in 100 year flood stage at the crossing is approximately 1096.5 m. The corresponding mean depth of flow and average velocity would be about 3 m and 4 m/s respectively. Construction of the recommended bank stabilization berms will increase the depth and velocity at design flows due to restriction of the channel section.

2.4.2 River Training / Bank Stabilization

Since the proposed stabilization berm along the west valley slope will block flow in the existing main river low flow channel, it will be necessary to construct a new waterway opening in the eastern floodplain area, and to provide measures to protect against excessive erosion during design flood conditions. The layout of the proposed works is shown on Drawing 2.1. The works consist of:

(a) an excavated channel with a bed elevation of approximately 1093.0 m and a bottom width of approximately 70 m.

(b) heavy rock rip rap armouring (Class III) on both the excavated channel sideslopes and stabilization berms, and

(c) a short, armoured guide bank extension to the west stabilization berm.

The latter is intended to establish relatively smooth parallel streamlines through the opening, and to prevent erosion and/or deep local scour by eddy action at the nose of the abutment.

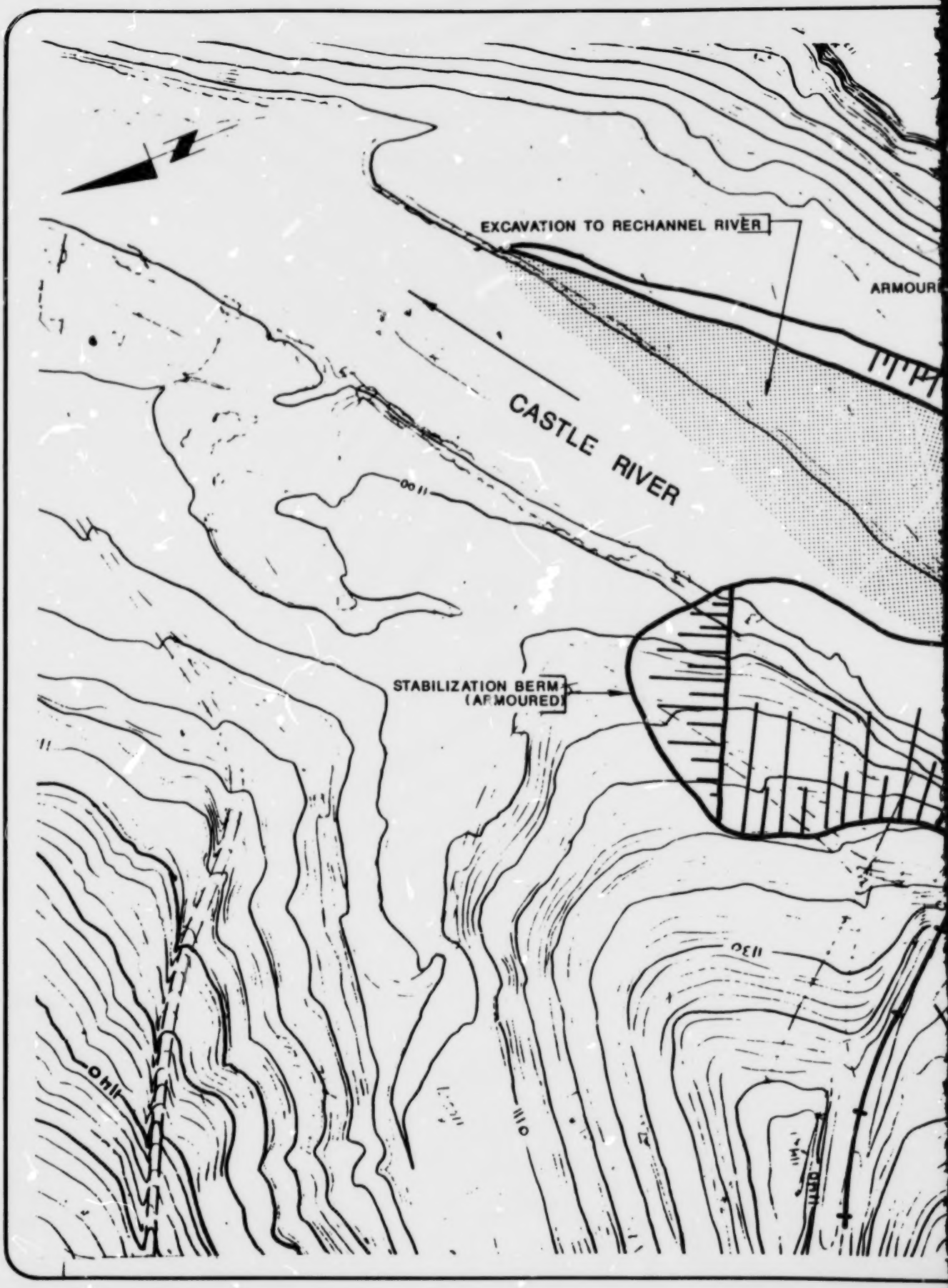
2.4.3 Pier Erosion Protection

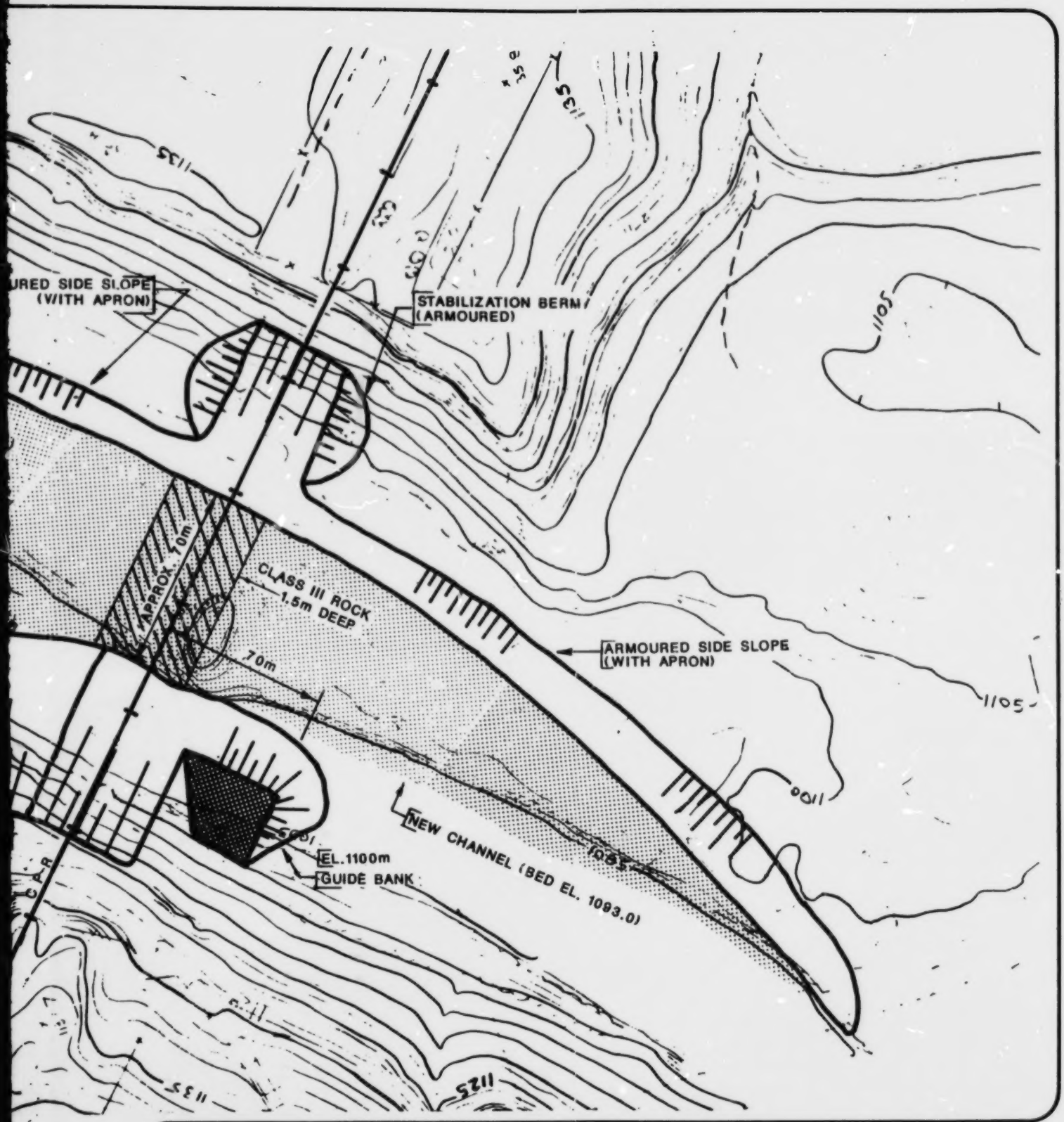
Computations indicate that average channel velocities at the bridge piers will be approximately 5.0 to 5.8 m/s for the principal structural options examined. Local velocities could be as much as 50 percent higher. Thus, an apron consisting of either oversized rock rip rap (D50 1.5m) or weighted concrete blocks (say 1m x 1m x 1m) will need to be placed on the channel bed for protection against deep local scour. For preliminary purposes, the upstream and downstream limits of the apron are proposed to extend 5 m and 15 m beyond the ends of the piers respectively.

2.5 STRUCTURAL ALTERNATIVES

2.5.1 Design Considerations

As field data have been obtained and assessed, and reservoir operating guidelines


EXCAVATION TO RECHANNEL RIVER
ARMOUR
CASTLE RIVER
STABILIZATION BERM
(ARMOURED)



Alberta ENVIRONMENT	Project	OLDMAN RIVER DAM RESERVOIR RELATED WORKS			
Prime Consultant STANLEY ASSOCIATES ENGINEERING LTD.	Title	C.P.R. BRIDGE – RIVER RETRAINING WORKS			
Subconsultant	Approved	Date Of Issue	Revision Number	Dwg. No.	2.1

developed, the structural options have been evolved with close interaction between the structural design team and the geotechnical engineers.
Thus, structural concepts were assessed by the geotechnical subconsultants in the framework of the developing information on rock strength and site geology, and the structural systems refined in light of the geotechnical recommendations.

Apart from assessing protective measures needed to mitigate the effects of reservoir flooding, a principal constraint has been CP Rail's requirement that rail traffic be maintained on the line throughout the construction period. In this regard, CP Rail have advised that it would be practical to schedule time slots of 4 to 5 hours duration per day to change bearings, or for other work that affects the existing structure, provided CP Rail inspectors are on the site to control traffic. The systems considered respect this requirement. CP Rail has indicated that it may also be possible to arrange longer periods of shutdown on occasion, if needed. This possibility has not been explored in detail, pending discussions with CP Rail on the concepts proposed.

2.5.2 Superstructure Loads

The structural concepts have been assessed considering Cooper E80 axle loads, dead loads, impact, wind loads, longitudinal forces and other forces in accordance with AREA specifications.

2.5.3 Substructure Loads

The modified or new substructure needs to support the superstructure loads described, as well as earthquake forces and new ice forces (applied at about elevation 1110 meters). Each of these forces is reviewed briefly below.

Ice Forces:

Ice forces consist of forces acting in the direction of flow in the reservoir, as well as forces transverse to the direction of flow in the reservoir.

Ice forces in the direction of flow in the reservoir are mainly caused by the impact of wind-driven ice floes (or "sheets") against the upstream end of the piers. These forces

occur primarily during spring break-up of the winter ice pack. These forces act in a direction essentially parallel to the long axis of the pier, unless the pier is skewed to the direction of flow. Ice floes will, therefore, produce forces at reservoir surface level, which act perpendicular to the bridge (in the strong direction of pier bending), coupled with transverse components due to ice floes coming in contact with the pier end at a skew angle.

Ice forces which act transverse to the direction of flow in the reservoir, can also occur. These forces cause a lateral "jacking" of the pier, and are caused by re-freezing of a previously frozen ice sheet, accompanied by expansion of the ice sheet (through water infilling of thermal shrinkage cracks). Ice forces transverse to the reservoir, act in a direction which is predominantly perpendicular to the weaker axis of piers. These forces are, therefore, generally parallel to the direction of the bridge.

The two types of ice forces, which act longitudinally and transversely to the direction of flow in the reservoir, do not act simultaneously. The magnitude of the ice forces will vary according to the size and shape of the new substructure alternatives. Forces were determined for each substructure alternative by Northwest Hydraulic Consultants Ltd.

Earthquake Forces:

The alternatives were assessed according to the AREA specification considering the seismicity study undertaken by UMA/Acres in August 1985 for the Oldman River Dam project. (Extracts from this report are quoted on pages E-9 and E-10 of Appendix E of Stanley's Part 1 Report on Reservoir Related Works.)

2.5.4 Crossing Alternatives

Initial consideration was given to five basic options. These included a new structure with associated rail realignment; causeway options at the existing crossing location, with buried conduits, or tunnels through the abutments; and reinforcement of the existing structure. Some options contained several variations, such that thirteen alternatives were evaluated during the course of the study. The options are briefly reviewed below.

Option 1

This option was based on mass piers located at the existing bents. Four alternatives of this option were investigated. Two alternatives with different size and shape of piers were developed in more detail (Alternatives 1 and 2). These alternatives involved use of gravel or lean concrete for filling material inside each pier.

Option 2

The concept considered with this option, involved new piers constructed between the existing bents, supporting a new continuous girder system to support the upper portion of the existing bents. Three alternatives were investigated in this option (namely, 3, 4 and 5).

Option 3

In this option, piers with a smaller cross-section would be constructed up to the underside of the superstructure. Two alternatives were developed, designated Alternatives 6 and 6A. The Alternative 6 concept located the piers at each bearing of the superstructure. Thus, twelve new piers would be required. In the second alternative, the new piers were contemplated to be located only at each second bearing, with a new superstructure spanning between the new piers.

Option 4

This option, involving two alternatives (7 and 8), considered replacing a portion of the bridge substructure, or the entire bridge by a causeway with conduits to carry River flows. The causeway top elevation was set at FSL for Alternative 7 and at the Base of Rail for Alternative 8. Cost estimates for the causeway option alternatives were much higher than the structural systems described above, thus, this approach was not developed further.

Option 5

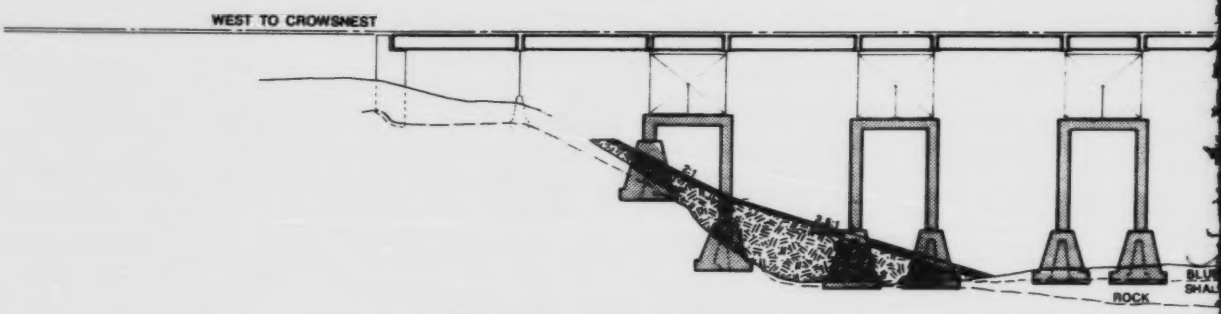
With this option, the existing legs of the bents would be encased in concrete to produce an A-Frame. Two alternatives were considered (namely 10 and 10A). With Alternative 10, the A-Frame would be constructed up to the underside of the existing plate girders. In Alternative 10A, the A-Frame would be constructed to the first pier frame above the FSL level, with the upper sections of the existing steel bents supported on new bearings on the A-Frame. This latter system has the lowest estimated cost of all options examined.

At an early stage in the study, three of these alternatives (1, 2 and 6) were submitted to CP Rail for preliminary comments. The comments received were considered when subsequent systems, including Alternatives 10 and 10A, were developed.

2.5.5 Recommended Structural System

The least cost option described above is recommended. This Alternative, 10A, is illustrated on Drawing 2.2. It involves encasement of the legs of the existing bents up to FSL, founded on revised, enlarged concrete footings. Extraneous cross-bracing would be removed up to the top of the new legs. Each steel leg woud be cut at the top of the concrete encasement section with a new bearing installed under each. One leg would be done at a time, such that the allowable four hours shutdown of rail traffic would be respected.

Total costs for each option are a function of the structural component described, and geotechnical systems needed to stabilize the abutments, as well as rechannelization required to divert flows at low reservoir operating levels through the resultant waterway after the slope stabilization fills have been constructed. The total estimated cost for the preferred system follows.



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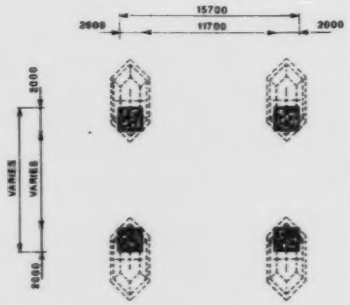

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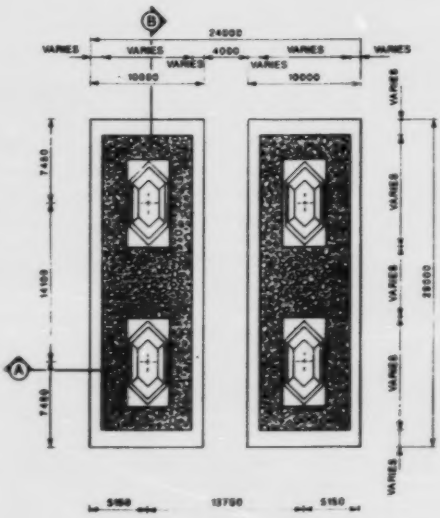

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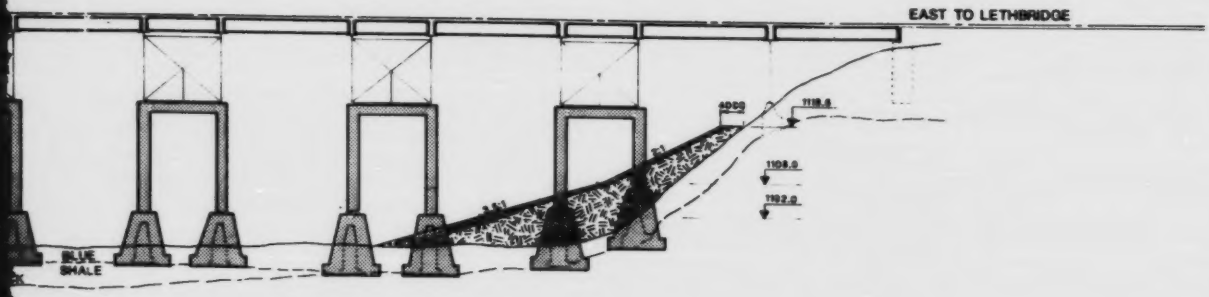

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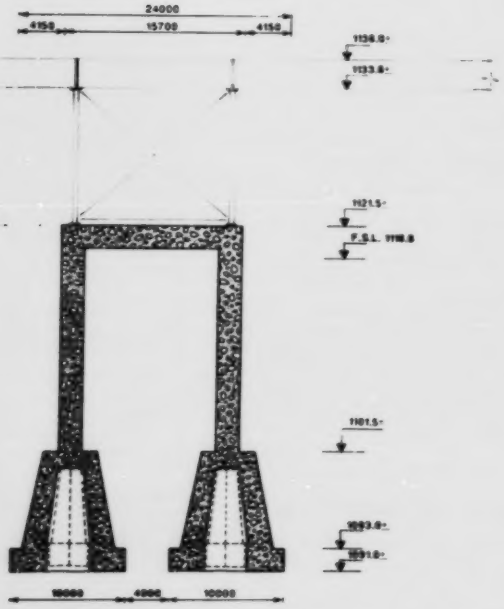
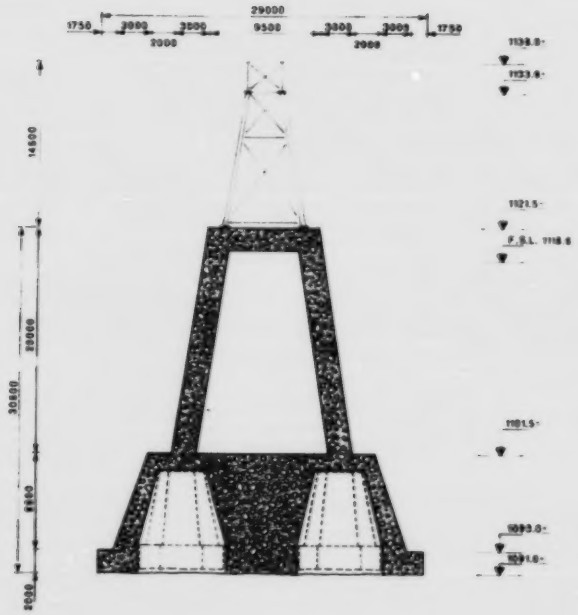


LONGITUDINAL SECTION 'A'



CROSS SECTION 'B'

Alberta ENVIRONMENT	Project: OLDMAN RIVER DAM RESERVOIR RELATED WORKS			
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title: ALTERNATE 10A C.P.R. BRIDGE			
Subconsultant	Approved	Date Of Issue	Revision Number	Dwg. No. 2-2

METRIC

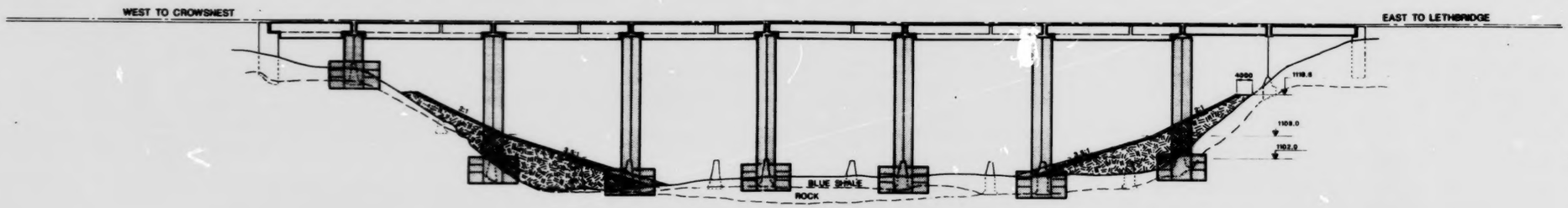
2.6 PRELIMINARY COST ESTIMATE CP RAIL BRIDGE PROTECTION

-	Structural Elements	$ 13,200,000
-	Abutment Stabilization	1,278,000
-	Approach Stabilization	482,000
-	River Retraining and Erosion Protection	2,991,000
	Total Estimated Construction Cost	$ 17,951,000
	Estimating Contingency and Engineering Provision (25% of Stabilization and River Works and 10% of Structural Elements)	2,508,000
	TOTAL ESTIMATED COST TO PROTECT CP RAIL BRIDGE	$ 20,459,000

2.7 ALTERNATIVE NEW STRUCTURE AND RELATED COST ESTIMATE

The least cost alternative has been recommended, however, CP Rail may wish to take this opportunity to replace the entire bridge. In this event, one option that would permit virtual replacement on the same alignment is the scheme designated Alternative 6A.

This alternative is illustrated on Drawing 2.3.



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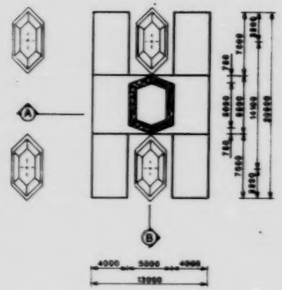
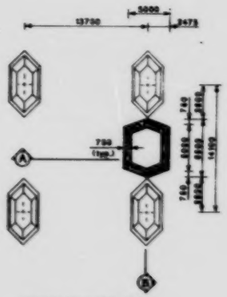


LOWER BOX SECTION & FOOTING LAYOUT



UPPER BOX SECTION

LONGITUDINAL SECTION 'A'

CROSS SECTION 'B'

METRIC
ALL DIMENSIONS ARE METRIC UNLESS OTHERWISE NOTED

Alberta ENVIRONMENT	Project	OLDMAN RIVER DAM RESERVOIR RELATED WORKS		
Prime Consultant STANLEY ASSOCIATES ENGINEERING LTD.	Title	ALTERNATE 6A C.P.R. BRIDGE		
Subconsultant	Approved	Date Of Issue	Revision Number	Dwg. No. 2.3

SECTION 3
HIGHWAY 3 BRIDGE

3.1 GENERAL

The location of the Highway 3 bridge over the Castle River is shown on Drawing 1.1 It too is located within the area that will form part of the new Oldman River Dam Reservoir. Thus, consideration has been given in the study to abutment protection, river hydraulics and structural implications of new effects resulting from construction of the Reservoir.

3.2 EXISTING STRUCTURE AND APPROACHES

This structure consists of four straight simple span concrete multi-girders. The span arrangement is approximately 36-38-38-36 m. Each span consists of seven precast prestressed AASHTO girders which support a 165 mm reinforced concrete deck slab and a 50 mm asphalt wearing surface. The bridge accommodates a 13.4 m clear roadway.

The substructure consists of two concrete abutments and three concrete "hammerhead" type piers. The central pier is founded in the shale bedrock while the other piers and the abutments are supported by steel H-piles. Loads from the girders are transferred to the substructure through steel rocker bearings.

The bridge slopes downward from east to west. The east abutment seat elevation is 1131.8 meters and the bottom of the girders are at 1132.2 meters. The west abutment seat is at 1127.3 meters and the bottoms of the girders are at elevation 1127.7 meters. The riverbed at the crossing is at approximately elevation 1108.5 meters and the base of the central pier is at about elevation 1110 meters. It is apparent from these elevations that when the reservoir is at FSL (1118.6 meters), there will be some 9 meters clearance to the underside of the girders and at winter operating levels at or below elevation 1110, that no new ice forces will impinge on the piers. Thus, the major considerations at the Highway 3 Bridge are for abutment and approach stabilization and to provide river

retraining and channel protection works necessitated as a result of the constriction that will result from abutment stabilization measures. These factors are addressed in this preliminary study under two headings:

- Geotechnical Assessments and Recommendations, and
- River Engineering Assessment.

Cost estimates for the proposed works follow.

3.3 GEOTECHNICAL ASSESSMENTS AND RECOMMENDATIONS

A report on the preliminary geotechnical investigations and recommended remedial work is bound into this report as Annex B. The conclusions and recommendations from this annexed document are repeated below.

3.3.1 Conclusions

1. The bedrock at the Highway No. 3 crossing belongs to the Willow Creek formation. A bedding dip angle of 14° in the direction N50°E has been used for the present study. However, additional drill hole data is required for final design in order to better define the bedding dip angles and direction across the valley. Once the bedding dip data has been determined a sensitivity analysis should be done comparing a bedding strength of 13° versus 15°. If a higher strength indicates a potential cost saving for stabilization of the crossing then a detailed investigation with large diameter holes (LDH's) would be warranted.

2. Based upon present data, buttress fills of free draining gravel are required at both abutments and along the side slopes of the approach fill.

3. Due to anticipated high flow velocities under the bridge, protection of the berms and center pier must be carefully analyzed during final design.

3.3.2 Recommendations

1. Abutment Stability

The steep slope at the east abutment is presently buttressed by a sand and gravel fill with a slope gradient of 2 horizontal on 1 vertical. Based upon the parameters discussed above a larger fill is required to stabilize the abutment under conditions of rapid drawdown. The analyses to date indicate that the berm should have a minimum top width of 3 m and a slope gradient of 3 horizontal on 1 vertical. The top of berm should be at elevation 1119 m. Compacted free draining sand and gravel should be used for berm construction.

In order to stabilize the interior slope of the west abutment a larger berm is required than proposed for the east abutment. The free draining gravel berm should be a minimum of 10 m wide at the top with a slope gradient of 3 horizontal on 1 vertical. The top of berm under the bridge should be at elevation 1119 m.

The Sketch on Drawing No. 2062.302 (Annex B) shows the assumptions made in the analyses of the east and west abutments. Drawing No. 2062.303 (Annex B) shows the plan and profile of the stabilization works proposed.

2. Approach Fill Stability

Except for the sand and gravel fill placed at the west abutment, the majority of the approach fill appears to be comprised of clay which has much lower strength than the sand and gravel at the abutment. Stability analyses indicate that a berm with a top width of 10 m and side slopes of 3 horizontal on 1 vertical will be required. Because the clay fill will not drain quickly under conditions of rapid drawdown, the berm must extend to elevation 1122 m. The top of the berm must transition from an elevation of 1119 m at the abutment to elevation 1122 m along the approach fill. Drawing No. 2062.303 (Annex B) shows a plan and profile of the proposed berms.

3. Slope Protection

The interior stabilizing berms at the bridge will significantly reduce the cross section of the channel under the bridge thereby creating a condition of high

velocities under low river flows. Protection of the berms from erosion and of the center pier from scour must be carefully reviewed during final design.

3.4 RIVER ENGINEERING ASSESSMENT

The Castle River channel in the vicinity of the Highway 3 Bridge is similar to that at the CP Rail Bridge two kilometers downstream. The proposed stabilization berms at the Highway No. 3 bridge crossing will significantly reduce the available waterway area. Computations indicate that average velocities of about 6 m/s can be anticipated in the constriction during design flood conditions. Since local velocities adjacent to the pier could be as much as 50 percent higher, an apron is needed on the channel bed for protection against deep local scour at the pier. For preliminary purposes it is proposed that either oversized rock rip rap (D50≈1.5m) or weighted concrete blocks (say 1m x 1m x 1m) be placed on the riverbed from 5m upstream to 15m downstream of the piers in the channel.

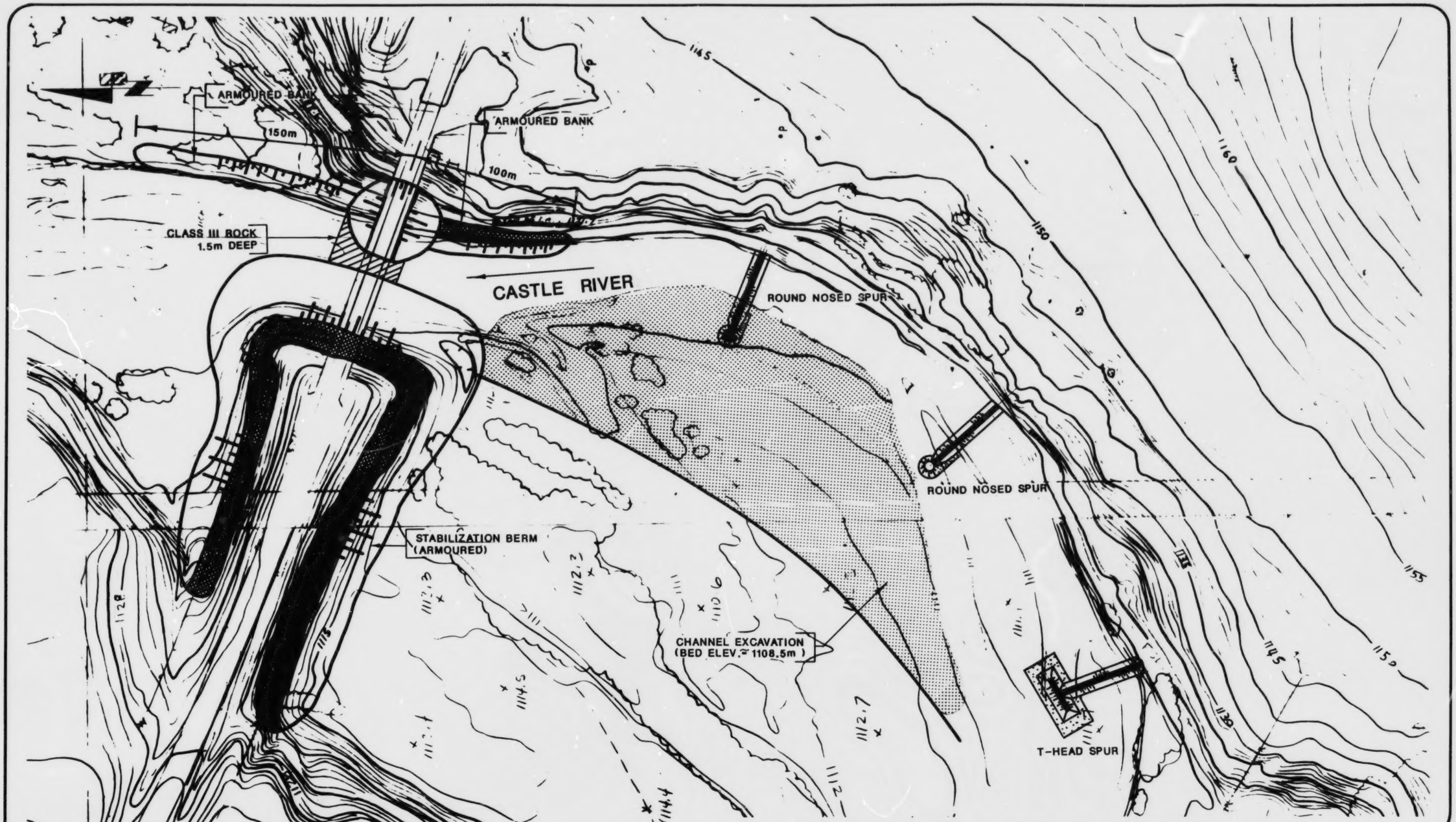
The river channel immediately upstream of the crossing presently impinges on the east valley wall. The result is a severe angle of attack and high local velocities at the upstream end of the east slope stabilization berm. Work is therefore needed to relocate the main channel away from the valley wall so as to channel the flow more directly through the restricted waterway opening.

The proposed river engineering works for this crossing are shown on Drawing 3.1. The works consist of:

(a) A 50 m wide channel excavation (bed elevation of approximately 1108.5 m) upstream of the crossing.

(b) Heavy rock rip rap armouring (Class III) on both the stabilization berms and the east bank approximately 100 m upstream and 150 m downstream of the crossing, and

(c) a series of spur dikes along the east valley wall to redirect the flow through the opening. As the spurs will be under direct attack during design flood conditions, their noses also need to be protected with a heavy rock apron and slope protection (Class III).



Alberta ENVIRONMENT	Project: OLDMAN RIVER DAM RESERVOIR RELATED WORKS			
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title: HWY. No.3 BRIDGE - RIVER RETRAINING WORKS			
Subconsultant	Approved	Date Of Issue	Revision Number	Dwg. No. 3.1

3.5 STRUCTURAL ASSESSMENT

During earlier stages of study it was anticipated that ice forces could be applied up to FSL at elevation 1118.6 meters. This level of ice force application would affect the pier in the river, thus remedial structural works were previously considered. Final advice from Alberta Environment is that the maximum winter operating level will be elevation 1110 meters. This is at the base of the existing pier, thus there will be no new effect on the structure due to ice, as a result of creation of the Reservoir. Consequently, no structural modifications are proposed.

3.6 PRELIMINARY COST ESTIMATE - HIGHWAY 3 BRIDGE PROTECTION

- Abutment and West Approach Stabilization	$ 2,393,000
- River Retraining and Erosion Protection	2,227,000
Total Estimated Construction Cost	$ 4,620,000
Estimating Contingency and Engineering Provision at 25%	$ 1,155,000
TOTAL ESTIMATED COST TO PROTECT THE HIGHWAY 3 BRIDGE	$ 5,775,000

SECTION 4
SCHEDULE AND COST SUMMARY

4.1 SCHEDULE

Alberta Environment intend to commence filling the Reservoir in the fall of 1990. Thus, for preliminary planning purposes, it has been assumed that remedial protective work at the CP Rail and Highway 3 locations should be planned for completion by the end of 1990. The following design and construction schedule (Drawing 4.1) anticipates this timing. As reservoir operation planning progresses, however, some leeway may become evident, before filling reaches the elevation of the riverbed at the CP Rail crossing (i.e., approximately elevation 1093). The schedule shown anticipates a full construction season will be available in 1990 before Reservoir flooding reaches the CP Rail bridge location. This will allow a somewhat later start for design and construction of these aspects of the Reservoir Related Works than is indicated in the tentative schedule illustrated in the Part 1 Report.

4.2 COST SUMMARY

Cost estimates for protective works at the CPR and Highway 3 Bridges are presented in Sections 2 and 3. Total cost estimates, including an allowance for contingencies and engineering are as follows:

-	CP Rail Bridge Protection Works	$20,459,000
-	Highway 3 Bridge Protection Works	5,775,000
	TOTAL	$26,234,000

These costs are additive to the costs presented in the Part 1 Report to determine total budget costs for the entire Reservoir Related Works aspects of the Oldman River Dam Project.

NOTE :

▨ DENOTES ASSUMED WINTER SHUT-DOWN PERIOD

Alberta ENVIRONMENT

Prime Consultant
STANLEY ASSOCIATES ENGINEERING LTD.

Subconsultant

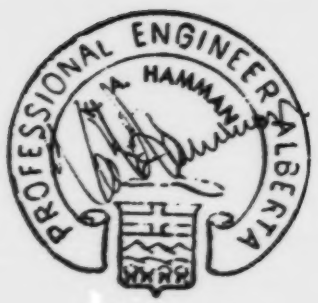
Project
OLDMAN RIVER DAM
RESERVOIR RELATED WORKS

Title
C.P.R. & HWY. No.3 BRIDGE PROTECTIVE WORKS SCHEDULE

Approved	Date Of Issue	Revision Number	Dwg. No.
	87-06-25		4.1

CORPORATE AUTHORIZATION

This report entitled "Oldman River Dam Reservoir Related Works Preliminary Engineering Report, Part 2 of 5, C.P.R. and Highway 3 Bridges, Geotechnical Investigations and Structural Protection Measures" has been prepared by Stanley Associates Engineering Ltd.



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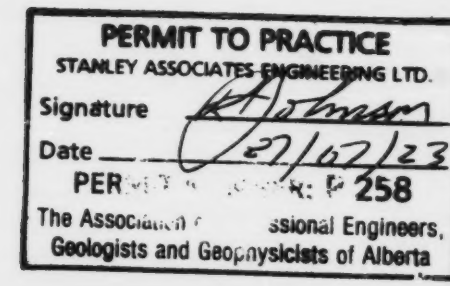

Company Permit

REPORT

OLDMAN RIVER DAM - RESERVOIR RELATED WORKS

CPR BRIDGE CROSSING - GEOTECHNICAL ASSESSMENT

for

STANLEY ASSOCIATES ENGINEERING LTD.

PA 2062

April 1987

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DRAWINGS

1.0 INTRODUCTION

The purpose of the geotechnical investigation at the CPR bridge over the Castle River was to assess the impact of the reservoir on the stability of the bridge abutments, piers and side coulees adjacent to the approach tracks and to recommend methods of stabilizing the structure and approaches. At full supply level (F.S.L.) the reservoir will be 22 m to 25 m deep at the CPR crossing. Upon drawdown of the reservoir, the induced pore pressures in the valley slopes will decrease the slope stability.

There are side coulees adjacent to each of the approach tracks on both sides of the valley. Instability presently exists in the side coulees and movements can be amplified by reservoir drawdown. Therefore, designs were developed to prevent these movements from occurring and ensuring stability of the bridge abutments and piers under reservoir operation.

2.0 EXISTING CONDITIONS

The CPR bridge crosses the Castle River in the W 1/2 13-7-1-W5M where the river channel flows in a north-easterly direction. The river elevation is approximately 1094 m and flows adjacent to the west side of the valley. The floodplain terrace is approximately 120 metres wide along the east side of the Castle River and ranges in elevation between 1097 and 1098.

The east side of the valley slopes at a gradient of 40° to 45°, and has experienced some failures 150 to 300 m downstream of the bridge crossing. Bedrock is exposed on the east slope beneath the CPR bridge at elevation 1123 m. The upland area to the east of the valley is relatively flat at an elevation of 1130 m.

The west side of the valley rises relatively steeply to elevation 1138 m and then continues rising gently to the west. The slope appears stable at the bridge site. However, a large flow slide has occurred at the outside of the river bend 500 m upstream of the bridge.

The CPR bridge measures approximately 288 m between abutments and supports a single track. The bridge spans alternate at 22.9 m and 13.7 m in the center of the valley and are 22.9 m at the abutments. Fourteen bents support the spans. Each bent is supported by two concrete piers which, according to the 'as-built' drawings, rest on pad foundations on or within the bedrock.

Bents 1 and 14, adjacent to the east and west abutments respectively, are single bents. The other bents are grouped in pairs. Bents 3 to 12 inclusive in the center of the valley are 36 m in height, measured from top of pier to base of rail. The other bents at the abutments vary in height from 32.9 m to 10.7 m. The piers for bents 3 to 9 inclusive are 5.2 m high with base dimensions of approximately 7.5 m by 3.5 m.

The piers for bents 3 to 12 inclusive are 14.1 m apart measured centre to centre. The piers for the remaining bents are varying distances apart; from 5.7 m (bent 14) to 13.1 m (bent 2).

Approximately 900 m east of the bridge the track borders a coulee. Slope movements in the coulee have resulted in the need for regular maintenance. On the west side of the bridge the track has been constructed along the south side of a coulee. A large number of past slope movements have resulted in various remedial works including piling, berms and subsurface drains.

3.0 PROPOSED STRUCTURE

Flooding of the reservoir and its operation will apply new external forces to the bridge and its foundations. Drawdown of the reservoir can cause instability in the abutments due to sliding on weak shear planes in the bedrock.

Several different schemes are proposed to replace the steel bent support system with a reinforced concrete structure. The schemes range from A-frames to column and beam to single columns. However, each scheme presently proposed is supported by either one or two large pier footings. Each pier footing is either 10 m by 20 m or larger. The existing pier footings are either incorporated into the foundation or will be removed after the replacement bridge is built.

4.0 1985 TEST HOLE PROGRAM

Three test holes were drilled on the west abutment for an initial assessment of abutment stability. Test holes 85-1 and 85-2 were drilled on an existing trail under the bridge structure. These holes were approximately 25 m to 30 m upstream and downstream from the bridge, respectively. Test hole 85-3 was drilled on a knoll, northwest of the abutment. The three holes were drilled at close spacing to determine the continuity of a bedrock strata between holes, the bedrock dip and direction and the presence of weak shear zones.

The valley floodplain test holes 85-4 and 85-5 were drilled approximately 50 m upstream and downstream of the bridge, respectively. These holes were drilled to determine the bedrock strata underlying the bridge piers in the valley bottom, and to assess the apparent dip of the bedrock along the river valley axis and determine the presence of significant shear zones.

The east valley slope was investigated by test hole 85-6 to determine the soil and rock stratigraphy, groundwater conditions and presence of weak shear zones.

The large coulees to the west and east of the bridge were investigated by drilling test holes 85-119 and 85-115 respectively.

The purpose of the holes was to determine the soil stratigraphy, groundwater conditions, and bedrock strata which will be affected by reservoir impoundment.

Packer testing to measure in situ bedrock permeability was carried out in test holes 85-2 and 85-119.

Test hole locations are shown on Drawing No. 2062.100.

Bedrock core was logged in the field. Selected samples of the overburden and bedrock were tested to determine moisture content, Atterberg limits, and unit weight. Direct shear tests were carried out on two samples of bedrock from test hole 85-2. The results are presented on the test hole logs in Appendix I.

5.0 1986 TEST HOLE PROGRAM

In 1986 four test holes were drilled at equal spacing across the floodplain beneath the bridge. These holes were drilled not only to determine depth to bedrock but also to provide information on the stratigraphic profile between abutments. Test hole locations are shown on Drawing No. 2062.100, and the test hole logs are presented in Appendix I.

6.0 LDH PROGRAM

The drill hole investigations of 1985 and 1986 detected a series of weaker planes in the bedrock. Therefore, two large diameter holes (LDH) or vertical shafts were drilled, one on either side of the river to examine the bedrock closer and to obtain large cores for strength testing. The west LDH (LDH-W) and east LDH (LDH-E) were drilled approximately 60 m and 50 m downstream of bridge centreline respectively. The LDHs were located as close to the structure as feasible within the limitations of structure stability, steepness of slope, excavation volume and the removal of hard rock to obtain a

suitable drilling area. The LDH sites and access routes are shown on photos 1 and 2. The LDHs were approximately 1.1 m in diameter and were drilled with a cable tool (churn) drill. A protective steel rebar frame was wedged against the exposed rock for the entire length of the shaft to prevent spalling of larger pieces of rock. The bedrock strata and weak seams were logged by a geologist.

Selected weak seams were sampled by drilling horizontally with a 200 mm diameter core barrel mounted in a specially adapted cage. Water was encountered in both holes with the main inflow from a fractured sandstone layer which was encountered in both holes at about elevation 1090 m in LDH-W and elevation 1091 m in LDH-E. These elevations are 3 to 4 m below river level. Inflow was greater in LDH-W with rates of approximately 30 litres/minute. The shafts were dewatered prior to downhole activities with frequent pumping required when working at lower levels.

Recovered samples were photographed on site (see photo 3), banded, sealed in plastic wrap and foil, waxed and placed in shock insulated containers for shipment to the testing laboratory. The logs for the two LDH's are presented in Appendix I.

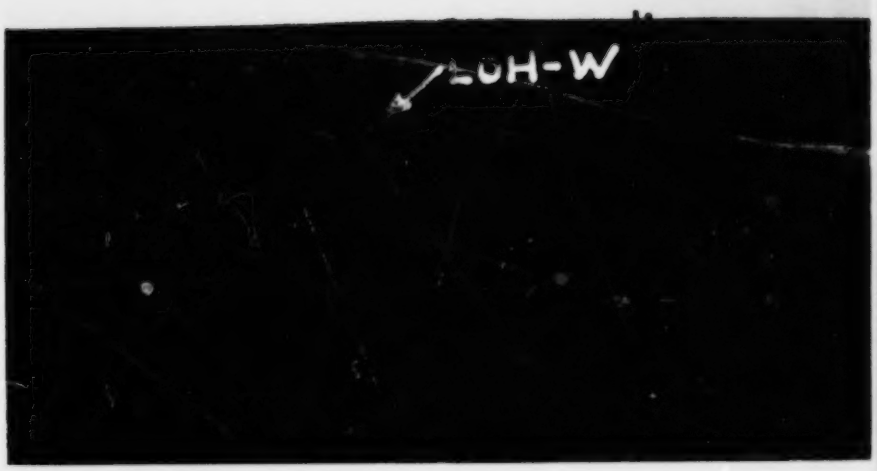
7.0 SITE GEOLOGY

The regional and reservoir geology has been covered in detail in the report entitled "Oldman River Dam Reservoir Boundary Study", dated December 1986. This report discusses only the geology at the CPR bridge.

An examination of the cores and the exposed rock in the shafts confirms that the bedrock at the CPR bridge is of the Willow Creek Formation. It comprises interbedded claystones, siltstones and sandstones with a predominance of claystones and siltstones. The beds dip in a general east to northeast direction consistent with other measured dips in this section of the reservoir. Several planar

PHOTO 1: Showing East LDH and access road with drilling rig on LDH-W in foreground.

PHOTO 2: Showing West LDH and access road.



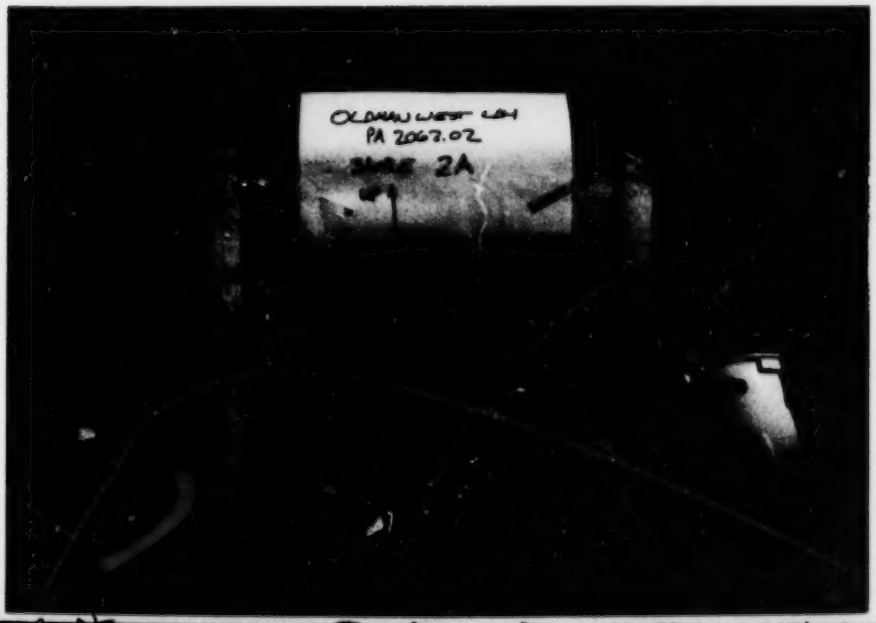


PHOTO 3: Showing sample 2A (LDH-W) prior to sealing for shipment to laboratory.

seams of weaker material , including a few well developed ones, were encountered in the LDHs. These seams could be extrapolated, on the basis of measured dip angle and direction, to zones of either core loss or weaker rock in the small diameter holes.

In the stratigraphic analysis of the test hole and LDH information, several marker beds or features were used. These comprised three sandstone beds and three claystone layers. The main weak seam, which supplied most of the samples in both LDHs, was also used to correlate between abutments. Initially the test holes, including LDHs, were divided into two groups. Group one included test holes on the west side of the river. Group two included test holes on the east side of the river. Test hole 85-115, drilled to investigate the stability of the coulee southeast of the bridge was considered to be too far from the other test holes to be included in the analysis.

The marker beds on the west side of the river gave consistent dips of 6° to 8° in the direction N70°E to N78°E with an average dip of 7° in the direction N75°E. This confirmed both the dip angle and dip direction obtained from the preliminary drilling results for the 1985 program.

The marker beds in the holes on the east side of the river indicated a dip of 7° in the direction N48°E. This indicated that the bedrock dip is downstream and almost exactly perpendicular to the longitudinal axis of the bridge. This is a revision of the estimate made in 1985 from measurements on sandstone outcrops on the east wall of the valley where it was believed the dip angle was 7° in the direction N70E.

There is good correlation between both sides of the river with the same sequence of beds and weaker seams occurring in holes on either side. However, from the information gathered and the analysis performed it would appear that there is a discontinuity, in terms of

strike direction, occurring under the present river channel i.e. closer to the west wall of the valley. It is believed that the discontinuity is a warped syncline caused by tectonic activities or compaction.

The stratigraphy is presented on Drawing No. 2062.100 as a section along the centreline of the bridge with the test hole and LDH stratigraphy projected onto the centreline. The section is broken under the river channel where the discontinuity was found.

8.0 LABORATORY TESTING OF LDH CORES

Laboratory testing of samples from the recovered core consisted of direct shear testing of specimens cut from the large cores, together with Atterberg limit testing to determine plasticity of material within the weaker seams.

On arrival at the testing laboratory the large cores were examined to determine the best portion for direct shear testing. In choosing a specimen, the orientation of the sample was taken into account, such that during testing the specimen would be sheared in a direction perpendicular to the alignment of the valley. The specimens were cut with a diamond tipped circular saw using water as the lubricating medium.

A typical test specimen, 60 mm square, consisted of a 4 to 8 mm shear zone of the weaker clay material sandwiched between 15 to 20 mm layers of claystone or siltstone. The claystone was generally brecciated, so a cement cap was cast over it to maintain its integrity during shear. As the shear zone was in some cases quite irregular, the gap between upper and lower sections of the shear box was increased to approximately 5 mm. Normal loads were set in accordance with the overburden pressure at sample elevations. For the peak cycle the displacement rate was set at 0.00096 mm/min and,

cycles, at 0.012 mm/min. These rates are the same as used for the direct shear testing carried out earlier in the project and were selected to avoid pore pressure build up in the failure plane.

On developing the peak shearing resistance, the machine was reversed to the zero starting point before performing the residual tests. This procedure was adopted rather than manually resetting the apparatus in order to minimize squeezing of the material. Up to 7 or 8 forward/reverse cycles were completed for each residual test.

The results of the residual portion of each test are combined graphically on Drawing No. 2062.101. All peak and residual strength test results are presented in Table 8.1. The graphical output of load and displacement from each individual test is shown in Appendix II of this report. A typical specimen is shown in photo 4. Atterberg limit test results are presented on the test hole logs in Appendix I and on Table 8.2.

The Atterberg limit test results indicate that the shear zone material is at the upper end of the medium plastic range. These results are also at the upper end of the range of Atterberg limit results obtained from testing samples of rock core from the 1985 reservoir drilling program.

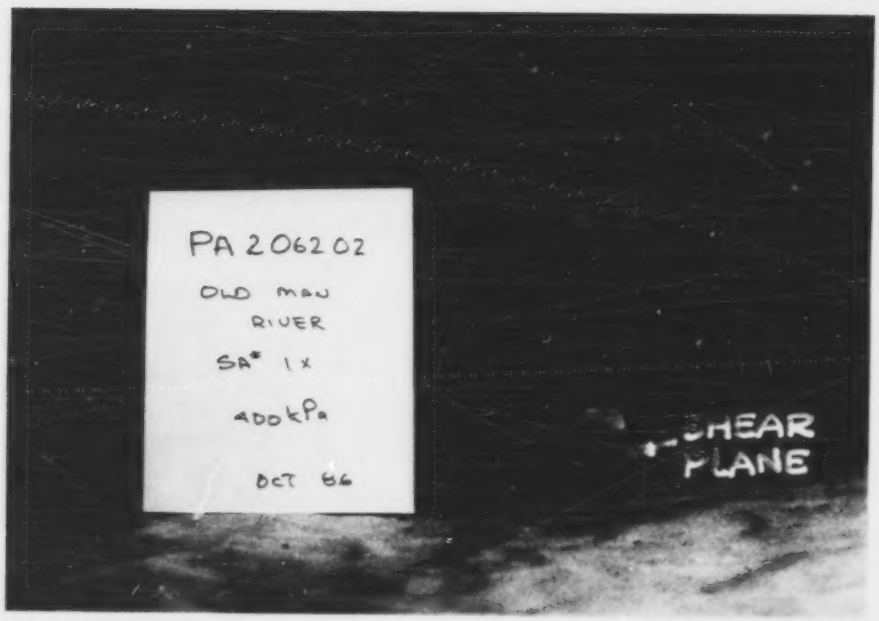


PHOTO 4: Showing specimen from Sample 1X (LDH-W) after testing.

TABLE 8.1

SUMMARY OF DIRECT SHEAR TEST RESULTS

Test	Peak Shear Load (N)	Peak Ang. (Deg.)	Residual Shear Load (N)	Residual Ang. (Deg.)
West 1081 1X 720 N, 200 kPa	196	15.2	256	*15.0 (19.6)
West 1081 1X 1440N, 400 kPa	254	10.0	355	13.8
West 1081 1C 720N, 200 kPa	273	20.8	161	12.6
West 1081 1Y 720N, 200 kPa	268	20.4	182	14.2
East 1082 1A 1440N, 400 kPa	532	20.3	400	*14.8 (15.5)
East 1082 1A 720N, 200 kPa	324	24.2	212	16.4
East 1082 1A 720N, 200 kPa	361	26.6	190	14.8
East 1082 1A 360N, 100 kPa	164	24.5	96	14.9
East 1082 1A 360N, 100 kPa	> 150	> 22.6	106	16.4
East 1082 1C 360N, 100 kPa	133	20.3	104	16.1
East 1082 1C 1440N, 400 kPa	> 405	> 15.7	400	15.5
East 1082 1C 720N, 200 kPa	322	24.1	115	**9.1
East 1082 1B 360N, 100 kPa	167	24.9	134	20.4
East 1082 1B 720N, 200 kPa	314	23.6	185	14.4
East 1082 1B 1440N, 400 kPa	372	14.5	360	14.0

* The shear plane is not horizontal, ramping effects are included to determine phi angle. Value in parenthesis is based on shear load only.

** Test was performed on a specimen comprising entirely remolded infill material. Residual phi angle cannot be considered applicable.

In some cases the peak shear load curve has not leveled off before residual test started. These test values are indicated by greater than sign (>).

TABLE 8.2

INDEX TEST DATA FOR DIRECT SHEAR TEST SAMPLES

Sample	Natural Water Content %	LL	PL
West 1C	18.4	NA	NA
West 1X	19.5	45	27
West 1Y	NA	44	26
East 1A	20.3	46	25
East 1B	22.1	48	27
East 1C	20.1	46	25

9.0 PARAMETER SELECTION AND STABILITY ANALYSES

The results of the direct shear testing on samples of the weaker seams at the CPR crossing were reviewed, (Drawing No. 2062.101), and a value of 14° was chosen for the residual effective friction angle, $\emptyset_r'$. As this value was based on tests on small specimens it was necessary to take into account variations in the bedding plane such as particle interaction and bed waviness. An allowance of 1° was added to the residual effective friction angle from the shear tests to account for the bed variations. Thus a residual effective friction angle, $\emptyset_r'$, of 15° was used in the stability analyses.

An effective cohesion, c', of zero was used from consideration of long term stability. Other material parameters were the same as used in the Reservoir Boundary Study. Table 9.1 summarizes the material properties used in the stability analyses. For details on the selection of the values shown in the table, see the report entitled "Oldman River Dam Reservoir Boundary Study" dated December, 1986.

TABLE 9.1
SUMMARY OF MATERIAL PROPERTIES
USED IN STABILITY ANALYSES

	Effective Friction Angle Ø' (deg.)	Effective Cohesion c' (kPa)	Bulk Density (kN/m^3)
FILL			
Free draining gravel	35	0	22.5
OVERBURDEN			
Glaciolacustrine Clay	19	0	20.5
Medium Plastic Clay Till	26	0	21.5
Gravel	30	0	22.5
WILLOW CREEK FORMATION BEDROCK			
Along Bedding	15	0	23.5
Cross Bedding (weathered)	40	50	23.5
Cross Bedding (unweathered)	40	150	23.5

Several assumptions were made regarding pore pressures in the slopes. The natural slopes are assumed to be drained near the face of the slope within a strip 10 m wide at F.S.L. and zero at the drawdown level. This partial drainage is assumed to occur in the fractured weathered rock but not in thick overburden where drainage was assumed to be zero. Pore pressures after rapid drawdown was assumed to be zero in free draining gravel fill.

A computer program using the Janbu method of computing stability along a composite failure surface was used to analyze the abutment and adjacent coulee slopes. A factor-of-safety of 1.2 would normally be sufficient for the case of rapid reservoir drawdown, where the probability of it occurring is infrequent. However, operation of the Oldman River Dam Reservoir, may see the water level at the CPR bridge

drop significantly on an annual basis. A higher factor-of-safety was therefore considered appropriate and has been set at 1.35.

10.0 BRIDGE ABUTMENT STABILITY AND PIER SUPPORT

10.1 Abutment Stability

The investigation indicated that a bedding plane with a design strength of 15° exists in the bedrock near the bottom of the river valley. At the west abutment the bedding plane dips at an angle of 7° at N75°E which results in a component of 3° parallel to the bridge. At the east abutment the bedding plane dips at an angle of 7° at N48°E which results in a component of 0° parallel to the bridge.

The stability analysis for rapid drawdown for the two abutments indicated factors-of-safety of 0.8 and 0.9 for the west and east abutments respectively. Therefore, stabilizing berms were designed to raise the factor-of-safety to the required 1.35. The recommended design is a composite slope of 3.5H:1V and 2H:1V as shown in section and plan on Drawing No. 2062.102. The results of the stability analysis for the berm design at the two abutments is presented on Drawing Nos. 2062.103 and .104.

The berm fill must be free draining gravel to meet the assumptions made in the stability analysis. It should be placed in lifts not exceeding 400 mm and compacted to a density of 97% Standard Proctor.

The berms must be protected from erosion. Details of the riprap design are presented on Drawing No. 2062.102.

Due to the restriction of the valley width caused by the berms, the lower portion of the valley will be subjected to high flow velocities at low water levels. Therefore, the heavy riprap design (Type A) is required below elevation 1102 and across the river valley as shown on Drawing No. 2062.102.

The light riprap design (Type C) may be used above elevation 1102 to the top of the berm. The specifications for the riprap and Type C bedding are as follows:

GRADATION OF RIPRAP

TYPE A (kg)			TYPE C (kg)		
W_{80}	$\geq$	1200	W_{80}	$\geq$	150
W_{50}	$\geq$	700	W_{50}	$\geq$	50
W_{20}	$\geq$	180	W_{20}	$\geq$	10

GRADATION OF BEDDING

Sieve Size	Range of Grading by % Passing
400	100
300	100-80
200	85-60
100	55-30
50	30-0
20	15-0

A layer of geotextile should be placed beneath the riprap.

10.2 Support of Piers

A review of the pier foundations was made for bearing and potential for sliding on weak shear planes in the bedrock. An allowable bearing capacity of 500 kPa is recommended for footings founded in the Willow Creek Formation.

A check was made of the footing resistance to sliding due to horizontal forces. A weak bedding plane was assumed near the base of the footing and a K_o = 1 for passive resistance was used. The calculated factor-of-safety is in excess of 1.5 providing the footing has minimum base dimensions of 5 m x 5 m.

It is assumed that all piers will be located within bedrock. Prior to placement of concrete the bedrock surface must be cleaned of all loose rock and debris. Careful use of compressed air will achieve the best results.

If the rock adjacent to the existing footings is badly disturbed it may be necessary to deepen the excavation beside the footing. However, existing footing support must not be disturbed and special anchors through the footings maybe required. Information on the bedrock should be gathered prior to construction in order to determine the elevation for the base of each footing excavation and the best means of ensuring the existing footing support is not disturbed.

10.3 Pier Stabilization

A special problem will exist for construction of the piers on the west and east valley slopes. Since larger piers will require excavation of the rock on the slope, potential undermining of existing pier support must be considered. A staged system of excavation and anchoring is recommended as shown on Drawing No. 2062.105. This drawing shows the proposed sequence of work for bents 12 and 13 on the west abutment. A similar support system should be developed for bent 2 on the east abutment.

Prior to commencement of excavation the bents should be drilled and anchored to the slope as shown on Drawing No. 2062.106.

As shown on Drawing No. 2062.107, each excavation stage should be no more than 2 m in height and reduced to 1 m if the rock is very weak. The excavation face should be shotcreted as soon as possible after excavation to prevent deterioration of the rock.

All rock anchors should be 10 m long and inclined 15° downward from the horizontal. Placement of the anchors should be staggered as shown on Drawing No. 2062.107 and a 500 mm square concrete anchor

head should be cast-in-place after each anchor is seated. After the concrete anchor head has cured, the anchor should be post-tensioned. Placement of anchor heads and tensioning of anchors should be undertaken as soon as possible after installation of the rock anchors and prior to commencement of excavation of the next stage. The effect of the post-tensioning should be to balance the horizontal earth pressure (active condition, K_A) including the component from the existing footing loads.

Excavation, foundation construction and backfilling should be synchronized. For example, on the west abutment, excavation of stages 8 to 12 should not be undertaken until construction of the foundation and backfill operations below the elevation of the upper bent (13) have been completed.

11.0 WEST COULEE STABILIZATION

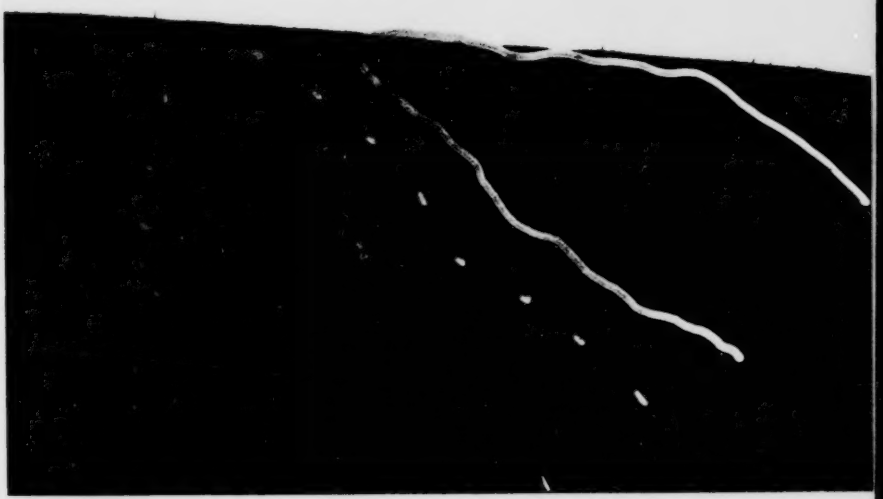
The west approach to the bridge, has been constructed along the south side of a coulee. Since construction, the cut-fill slope has been unstable, and several failures have occurred. Various remedial measures have been attempted including a timber pile retaining wall, a drainage system, moving the trackbed into the slope, and flattening the backslopes above the track.

In a report by Materials Testing Laboratory Ltd., dated October 21, 1968, a review was made of the previous attempts at stabilization and recommendations made to control seepage in the subsoil. Several recommendations were made including:

1) a 6 m deep gravel filled cut-off trench immediately upslope of the trackbed;
2) vertical wells drilled into the bedrock to lower the groundwater level in the slope;
3) horizontal drains augered into the slope, connected with the vertical wells, to remove groundwater from the slope; and
4) ditching upslope of the track to remove surface runoff and minimize percolation.

PHOTO 5: Showing remedial measures for old slide at Mile 65.8 and adjacent active slide. Note active slide outlined above and below rail line.

PHOTO 6: Showing close up of slides in photo 5 downslope from track.



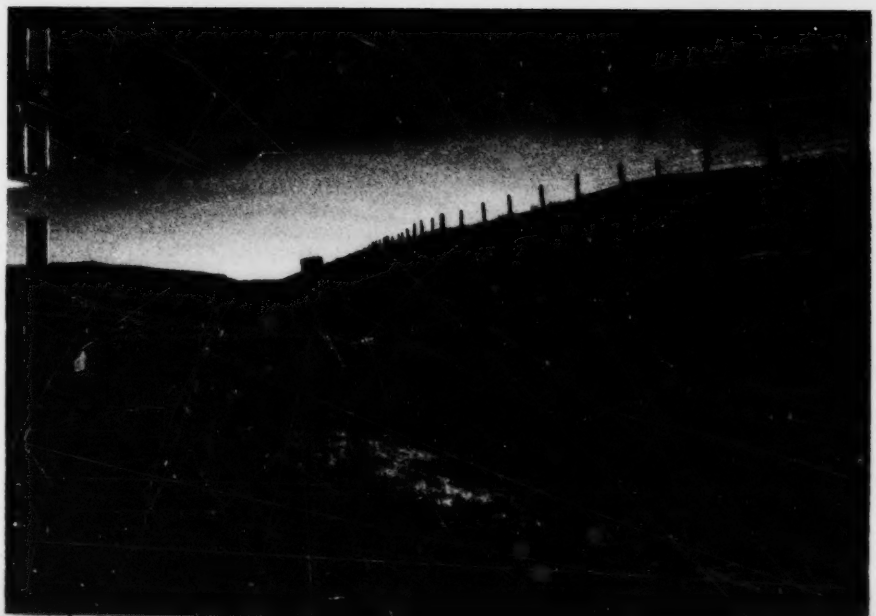


PHOTO 7: Showing active slide in photo 5 up slope from track (outlined).

Stabilization of the slope at mileposts 65.8 and 66.2 was carried out in the summer of 1970. It is not known, from the records available, whether all measures recommended in 1968 were incorporated. However, they appear to have been successful in reducing slope movements at these two mileposts.

A further study by CP Rail with Clifton Associates Ltd. (report dated December 2, 1979) reviewed the mechanics of instability along the coulee and suggested that the track construction had blocked the seepage path from the slopes and reduced stability.

Photo 5 shows a general area of instability which is immediately west of Milepost 65.8. Photo 6 and 7 show a closer view of the instability of the slope below the track and the slope above the track respectively. Photo 6 shows two pipes on the slope, one drain pipe and one half round culvert. These pipes, particularly the pipe at the top of the slope are probably discharging water onto the slide area below the track.

Based on our observations, it is considered that the cause of past and present slope failures at this location is groundwater blockage by the track fill and infiltration of runoff into the slope. It is believed that the failure surfaces are either within the soil layers, or tangent to bedrock. A similar conclusion has been arrived at in the previous reports.

Saturation of the toe of the slope by the reservoir and subsequent drawdown could create instability of the toe and result in a progressive slide. The instability would be amplified by the present metastable condition of the slope. Therefore, it is necessary to prevent movement of the toe by construction of a berm extending to F.S.L. For preliminary design, the berm should have a minimum slope of 3.5H:1V with a minimum top width of 6 m at F.S.L. as shown on Drawing No. 2062.108. Because the present slope varies in gradient and alignment, some adjustments in the berm slope gradient maybe

required particularly at local, presently unstable areas where slump debris has collected at the toe of slope. As the recommended berm will reach the other side of the coulee at many locations, it will be necessary to ensure ponding of surface drainage does not occur between the toe of berm and coulee slope. Additional filling maybe necessary to achieve a uniform ditch gradient along the coulee bottom. A detailed survey will be required to provide the final design data necessary for preparation of the construction contract drawings.

The surface of the berm should be protected by a layer of light riprap (Type C) and geotextile as recommended in section 10.1. A layer of geotextile should be placed below the riprap.

It is emphasized that the toe berm will not prevent continued instability of the portion of the slope above F.S.L. This portion requires further drainage control to lower the high water table in the slope and excavation to reduce slope gradients. It was not in our terms of reference to stabilize the overall CPR track but only to stabilize that portion of the track affected by the reservoir.

12.0 EAST COULEE STABILIZATION

Approximately 900 m east of the bridge crossing, the track approaches a large coulee to the south of the track. At its closest point the track crosses a small tributary gulley. Originally the track crossed the gulley on a small bridge which has been very recently (since 1985) replaced by a fill and culvert. Photo 8 shows the fill and unstable area downslope. Photo 9 shows the irregular alignment of a fence which crosses the unstable slope.

Similar to the west coulee, the instability of the slope on the east coulee is also due to groundwater blockage by the track fill.

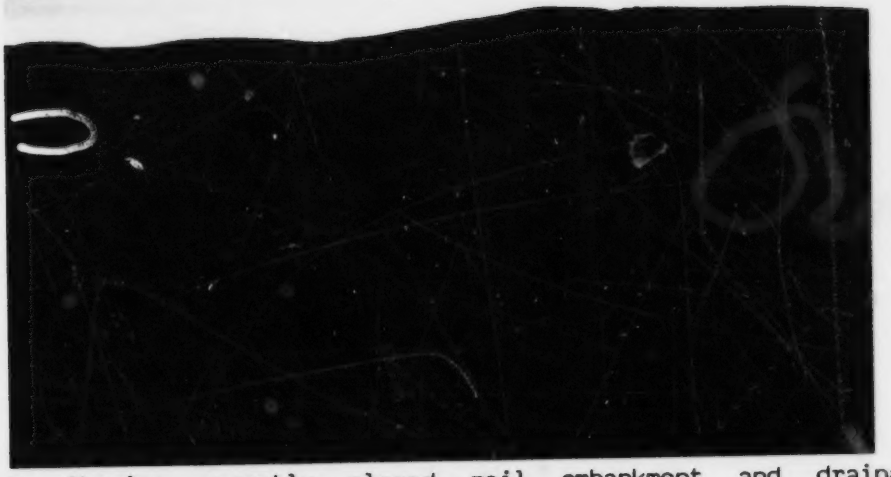


PHOTO 8: Showing recently placed rail embankment and drainage culvert. Hummocky terrain shows evidence of old slides. Two small flow slides are visible as dark areas on left of photograph.

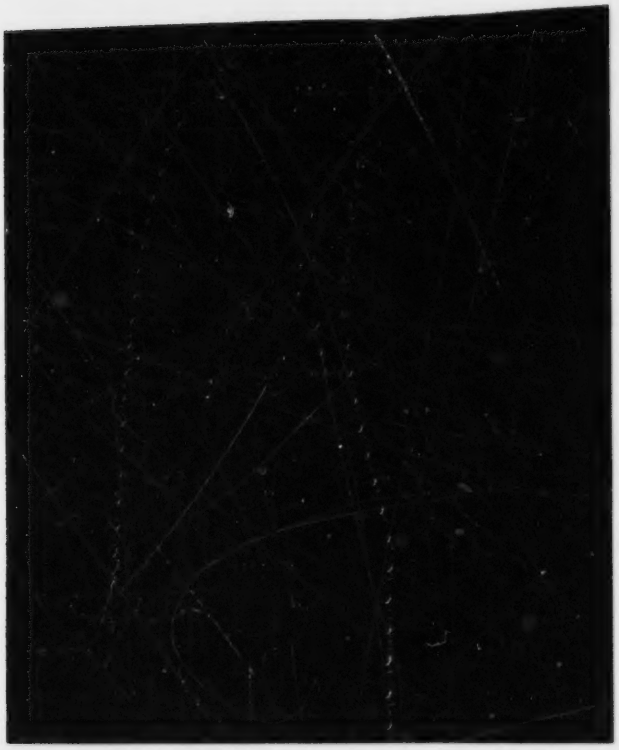


PHOTO 9: Showing fence line distorted by slope movements. Railroad to left of photograph.

The reservoir will approach the toe of the slope in this area of present instability. Saturation of the toe by the reservoir and subsequent drawdown will have minor impact except that the slope is believed to be very close to a factor-of-safety of 1 and any toe movement could impact the overall slope. Therefore, a small fill is recommended in the coulee bottom as shown on Drawing No. 2062.108. Natural flow in the coulee should be channelled in a ditch on top of the fill and the downslope edge of the fill should be protected from erosion by Type C riprap. This berm will not stabilize the overall slope but will eliminate the potential impact of the reservoir.

13.0 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations can be drawn from the present study.

1. The bedrock underlying the CPR bridge site belongs to the Willow Creek Formation. It dips at 7° to the N75°E on the west side of the river and at 7° to the N48°E on the east side of the river. Along the longitudinal axis of the bridge, the bedrock dip is at 3° towards the river on the west side and horizontal on the east side. Thin shear zones or weak seams parallel to the beds exist close to the toe of the slope under both abutments. The material within the shear zones is considered to have a strength equivalent to an residual effective friction angle $\emptyset'_r$ of 15°, with zero cohesion.

2. Both abutments require buttressing fills to provide an adequate factor-of-safety for slope stability during rapid reservoir drawdown.

3. New pier foundations with minimum horizontal dimensions of 5 m, in the valley bottom will be stable under a maximum projected horizontal force 12 000 KN. Temporary support or underpinning of the existing pier foundations may be required during construction depending on the condition of the rock at each footing.

4. The excavations around existing pier foundations, on the valley slopes, will require substantial temporary support to prevent movement of the existing foundations while the larger foundations are under construction.

5. The coulees to the west and east of the bridge presently show signs of instability due to high groundwater levels and blockage of drainage by track fills. Rapid drawdown of the reservoir would decrease the stability of the toes of the slopes and so stabilizing berms are recommended. These berms will not stabilize the overall slope but will only stabilize that portion of the slope affected by the reservoir.

Yours very truly,

KLOHN LEONOFF LTD.

PERMIT TO PRACTICE
KLOHN LEONOFF LTD.
Signature
Date April 21/87
PERMIT NUMBER: P 433
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

RICHARD MCLAREN, P.Eng.

DONALD M. DAVISON, P. Eng.
Vice President, Alberta Region

RM/DMD/sh

APPENDIX I

Test Hole and Test Pit Logs

A: 1985 Test Hole Logs

B: 1986 Test Hole Logs

C: 1986 LDH Logs

A: 1985 TEST HOLE LOGS

TH 85-1
TH 85-2
TH 85-2B
TH 85-3
TH 85-4
TH 85-5
TH 85-6
TH 85-115
TH 85-119

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.
Subconsultant: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 85 - 1

SHEET 1 of 6

CONTRACTOR(S) / DRILL RIG(S): B: SDS Drilling - Gardner Denver 1700

RIG No. ____ DEPTH(m) ____ DATE ____ HOLE DIAM. ____ TOP CASING A (El.) ____

RIG No. B DEPTH(m) 40.0 DATE Sep 27-29/85 CORE DIAM. 76mm TOP CASING B (El.) 1127.3m

LOCATION: NW 13-7-1-W5

COORDINATES: 5491339.0 N
-1474.6 E

INITIAL DIP: VERTICAL

ELEVATIONS: GROUND SURFACE: 1127.2m
ROCK SURFACE: 1121.4m
BOTTOM OF HOLE: 1087.2m

DEPTH ELEV. d-Dm	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.)	JTS per m	W.L. & INSTR.	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
1127.2									
5.60	Begin coring at 5.6m								
1121.6	TILL								
5.77	- clayey silt - orange brown								
1121.4	BEDROCK								
6	SANDSTONE - light yellowish brown - fine grained - very thinly bedded - moderately to highly weathered - strong		- 6.07 planar joint, 70°, rough Drilling breaks on bedding planes at 85°- 90° TCA	89 (89)	8				
7			- 6.68 planar joint, 30°, smooth, extremely narrow, fine sand infilling 6.80 irregular joint, 85°, rough, clay infilling - 7.20-7.53 clay lumps and ripple beds - 7.41 planar joint, 80°, rough 7.53 planar joint, 70°, smooth, opened by drilling	93 (93)	7				
8	light grey, medium grained, fresh with staining on some joints, very strong yellowish olive brown, fine to medium grained, very strong trace of claystone fragments and black coal laminations		Joints opened by drilling are parallel to bedding, 85°- 90° ..	100 (100)	6				
9									

ABBREVIATIONS:

JTS.	- JOINTS
CORE REC.	- CORE RECOVERY
R.Q.D.	- ROCK QUALITY DESIGNATION
W.L. & INSTR.	- WATER LEVEL & INSTRUMENTATION
K	- HYDRAULIC CONDUCTIVITY

SUBCONSULTANT: KLOHN LEONOFF LTD.

INSPECTOR:

LOGGED: TKH

APPROVED TKH

Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD
SUBCONSULTANT: KLOHN LEONOFF LTD

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 85 - 1
SHEET 2 of 6

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC (R.Q.D.) (%)	JFS per m	WL & INSTR	e (c-v)	TEST SAMPLE & TYPE	TEST RESULTS
	SANDSTONE cont'd - yellowish brown - fine to medium grained - very strong - trace of CLAYSTONE fragments - coal laminations		Bedding 85° TCA	100					
			-9.52 planar joint, 10°, very rough	(100)	4				
10				100					
				(100)	1				
11	Drilling fluid loss at approximately 11m		-11.05 planar joint, 40° smooth, narrow, trace of clay infilling						
11.26			11.10-11.26 possible shear zone						
1115.9	CLAYSTONE - dark greenish grey - moderately weathered		-11.44-11.51 slickensided surfaces 11.51-11.56 breccia zone	89	3				
				(86)					
12	CLAYSTONE - dark greenish grey to black - slightly silty - bedding is disturbed - fresh - moderately strong		-12.50-12.60 irregular slickensided surfaces at many different orientations -Joints, at 40°- 45°, slickensided discontinuous shears		4				
13			12.86-13.07 possible -core loss	86					
			13.23-13.25 shear, 75°, filled with clay gouge material	(86)	3			D 1	
			discontinuous shear zones						
14			-14.11 irregular shear, 10°, slickensided -14.24 planar shear, 24°, slickensided						
	siltier, stronger, less disturbed			99	2				
				(99)					
15	disturbed, breaks are mottled with blue grey and olive brown, moderately strong		-15.40 irregular joint, 40°, rough 15.64-16.05 5 irregular -to planar sheers, opened by drilling, slickensided at angles of 90°, 50°, 20°, 10		5				
				100					
16				(85)					

ABBREVIATIONS

Alberta ENVIRONMENT

OLDMAN RIVER DAM

HOLE No 85 - 1

SHEET 3 of 6

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD
Subconsultant: KLOHN LEONOFF LTD

DRILLHOLE LOG

DEPTH ELEV (m) 16.00	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC (R.Q.D.) (%)	JTS per m	WL & INSTR	c (t/m²)	TEST SAMPLE & TYPE	TEST RESULTS
1111.2	SILTSTONE - clayey - blue grey - fresh - thickly bedded - extremely strong		-16.40 planar shear, 20°, smooth, tight	100	4				
	zone of olive staining, moderately weathered		-16.85 planar joint, 90°, rough, tight	(85)					
17	CLAYSTONE: medium grey green, fresh, moderately strong		-17.55 curved joint, 20°, smooth, rust staining		5				
	SANDSTONE: fine grained, corss-bedded, contains CLAYSTONE fragments		-17.64 irregular joint, 80°, rough, rust staining 17.70 planar joint, 30°, smooth, calcite infilling	100					
18	SILTSTONE: dark grey, grading to fine SANDSTONE, laminated and cross-bedded		Bedding 85° TCA	(88)					
	CLAYSTONE: dark grey, weak SILTSTONE: yellowish to dark grey, moderately weathered		18.57 curved joint, 90°, smooth, rust staining joint: vertical, tight, weathered		4				
18.80									
1108.4									
19	CLAYSTONE - dark grey - laminated - carbonaceous partings - strong		-19.32 2 planar joint, 30°, -19.40 smooth, tight	100	2				
	SILTSTONE; dark greenish grey, fresh, very strong, slightly calcareous			(94)					
20	silty, dark greenish grey, laminated, strong, contains small hard calcite nodules, olive color, silty		Bedding trace of 85° TCA	100	2				
			-20.80 planar joint, 90°, rough, opened by drilling	(94)					
21			-21.02 planar joint, 80°, smooth 21.08-21.26 3 planar joints, 70°, smooth		8				
	SILTSTONE: light greenish grey, fresh, very strong		-21.84;21.90 2 planar joints, 50°, smooth						
22			-22.13-22.14 breccia zones -22.27-22.29 90°, softened claystone	100					
22.50			-22.36 irregular joint, 50°, smooth	(95)	4				
1104.7	SANDSTONE - light greenish grey - fine grained extremely strong - laminated - fresh								
23									

ABBREVIATIONS

Alberta ENVIRONMENT

prime consultant: STANLEY ASSOCIATES ENGINEERING LTD
subconsultant: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 85 - 1
SHEET 4 of 6

DEPTH ELEV (-)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	WL & INSTR	K (m/s)	TEST SAMPLE & TYPE	TEST RESULTS
	SANDSTONE cont'd		-23.08 planar joint, 20°, smooth	100					
23.29			Bedding 80° TCA	(95)					
1103	9 CLAYSTONE - silty - dark grey - laminated - fresh - very strong - carbonaceous partings on laminations		-23.70-23.77 breccia zone no slickensides	99 (89)	3				
24			2 joints, 80°, bedding planes, smooth, opened by drilling		4				
	becoming siltier		-24.55 irregular shear, -40°, slickensided 24.63 2 irregular joints, -24.78 50°, rough, opened by drilling						
25.00									
1102	2 SILTSTONE - contains small nodules of limestone or calcareous claystone			100	1				
	SANDSTONE: fine grained, very slightly calcareous			(100)					
26			-25.85 planar joint, 20°, smooth, rust staining						
26.28									
1100	9 CLAYSTONE - dark greenish grey to dark grey - fresh - moderately strong - some zones have high silt content		-26.47 planar joint, 10°, tight, smooth -26.64 planar joint, 45°, tight, smooth	100	3				
27			-26.91 planar joint, 60°, smooth	(97)					
			Bedding 80° TCA 3 drill induced breaks on bedding planes, 80°		4				
			-27.55 vein, clacareous, -4mm thick 27.68 irregular shear, 85°, slickensided						
28	laminated, extremely strong where silty and weak where clay rich, slightly calcareous, fossil shells on laminations		-28.20 curved joint, 10°, rough	99					
			-28.47-28.56 shear zone, 90°- 80°, sand and gravel size fragments, no slickensides	(99)	2				
29									
			-29.28-29.80 3 bedding joints, 80°, smooth, opened by drilling	100 (100)	3				
30									

ABBREVIATIONS

Alberta ENVIRONMENT

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 85 - 1
SHEET 5 of 6

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD
Subconsultant: KLOHN LEONOFF LTD.

DEPTH (m)	ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC (RQD) (%)	JTS per m	WL & INSTR	K (m/s)	TEST SAMPLE & TYPE	TEST RESULTS
		CLAYSTONE cont'd - dark greenish grey to dark grey - laminated - fresh - extremely strong where silty and weak where clay rich - slightly calcareous - fossil shells on laminations		- 30.75 irregular shear, 30°, slickensided	100 (100)	1				
31				- 31.00 planar shear, 55°, slickensided 31.10-31.56 possible core loss	71				D 2	
31.64					(65)	1				
	1095.6	SANDSTONE - light grey - with coal partings - fresh - extremely strong - cross-bedded - sinusoidal ripple drift		- 32.10-32.85 5 irregular shears with discontinuous slickensides, 50° - 60°, opened by drilling						
		CLAYSTONE; light blue grey				6				
32.82		SILTSTONE; blue green, extremely strong			100 (99)		Jan 11/86 Feb 6/86			
	1094.4									
33		CLAYSTONE - black to dark grey - some limestone pebbles up to 3cm diameter - fresh - strong		- 33.10-33.45 3 irregular shears with discontinuous slickensides 50° - 60°, opened by drilling		3				
34		becomes blue green with olive mottling		- 34.14-34.35 undulating joint, vertical, rough	100 (100)	0			D 3	
35				- 34.91 irregular joint, slickensided, orientation unknown		2				
35.58										
	1091.6	SILTSTONE - greenish blue grey - bedding is not visible - fresh - very strong								
36					100 (100)					
				- 36.41 planar joint, 20°, smooth, rust staining		1				
37										

ABBREVIATIONS

Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD

SUBCONSULTANT: KLOHN LEONOFF LTD

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 85 - 1

SHEET 6 of 6

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC (%O.D.) (%)	JFS per m	WL & INSTR	k (m/s)	TEST SAMPLE & TYPE	TEST RESULTS
	SILTSTONE cont'd								
	SILTSTONE; with some CLAYSTONE beds up to 10 cm thick		- 37.44-37.69 2 planar joints at 35°, rough, rust stained and moderately weathered	100 (100)	2				
38			- 38.00 planar joint, 65°, rough		1				
39				100 (100)					
39.50					0				
1087.7	SANDSTONE - medium greenish grey - very fine grained - fresh - extremely strong								
40.00									
1087.2	END OF HOLE @ 40.00m								

ABBREVIATIONS

Alberta ENVIRONMENT

Head Consultant: STANLEY ASSOCIATES ENGINEERING LTD

Subconsultant: KLOHN LEONOFF LTD

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. BS - 2

SHEET 1 of 7

CONTRACTOR(S)/DRILL RIG(S): B: SDS Drilling - Gardner Denver 1700

RIG No. ____ DEPTH(m) ____ DATE ____ HOLE DIAM. 140mm TOP CASING A (El.) --

RIG No. B DEPTH(m) 40.3 DATE Sep 29-Oct 1/85 CORE DIAM 76mm TOP CASING B (El.) --

LOCATION: NW 13-7-1-W5

COORDINATES: 5491381.1 N

-1440.7 E

INITIAL DIP: VERTICAL

ELEVATIONS: GROUND SURFACE: 1123.3m (approx.)

ROCK SURFACE: 1114.0m (approx.)

BOTTOM OF HOLE: 1083.0m (approx.)

DEPTH ELEV (m)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE STATE	SAMPLE No.	PENETRATION TEST (Blows/0.15m) S - STANDARD PENETRATION	UNCONFINED COMPRESSION kPa 100 200 300 400	PLASTIC LIMIT / WATER CONTENT / LIQUID LIMIT %	UNIT WEIGHT (kN/m³)	COHESION (kPa)	ANGLE OF SHEARING RESISTANCE φ° (Deg)	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY (cm/sec)	PARTICLE SIZE (%) Clay <0.002mm	Silt 0.074-0.002mm	Sand 4.76-0.074mm	Gravel 76.2-4.76mm
0.00																
1123	3															
1	CLAY(CH) - silty - soft to firm - high plasticity - olive brown			A 1												
2																
3	- firm to stiff			A 2												
				D 3												
4																

SAMPLE

- UNDISTURBED
- DISTURBED
- NOT RECOVERED

⊙ NATURAL WATER CONTENT (w)

LIQUID LIMIT (w_L)

PLASTIC LIMIT (w_P)

△ UNCONFINED COMPRESSIVE STRENGTH MEASURED WITH POCKET PENETROMETER

SAMPLING METHOD

A - SPLIT TUBE
B - SHELBY TUBE
C - PISTON SAMPLER
R - CORE BARREL
E - AUGER
W - WASH

SUBCONSULTANT : KLOHN LEONOFF LTD

LOGGED BY: IB

APPROVED TRH

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD

Subconsultant: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 85 - 2

SHEET 2 of 7

DEPTH ELEV (-)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE STATE	SAMPLE No.	PENETRATION TEST (Blows/0.15m) * - STANDARD PENETRATION	UNCONFINED COMPRESSION σ_3 kPa 100 200 300 400 Δ; PLASTIC LIMIT, WATER CONTENT, LIQUID LIMIT; 10 20 30 40 50 60 70 80 90%	UNIT WEIGHT kN/m³	COHESION (kPa)	ANGLE OF SHEARING RESISTANCE Φ (Deg)	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY K (cm/sec)	PARTICLE SIZE (%)
5	CLAY(CH) - silty - high plasticity - firm to stiff - olive brown			D 3		⊙						
				D 4		⊙						
6												
				D 5		⊙						
7	- boulder at 7.5m											
8												
9												
9.30												
1114	CLAYSTONE - refer to sheet 3			D 6		⊙						
10												

SAMPLE

- UNDISTURBED
- DISTURBED
- NOT RECOVERED

⊙ NATURAL WATER CONTENT (w)

— LIQUID LIMIT (w_L)

o— PLASTIC LIMIT (w_P)

Δ σ_3 UNCONFINED COMPRESSIVE STRENGTH MEASURED WITH POCKET PENETROMETER

SAMPLING METHOD

- S - SPLIT TUBE
- T - THINWALL TUBE
- P - PISTON SAMPLER
- D - LOOSE SAMPLE
- B - AUGER
- C - CORE

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.

Sub-Consultant: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 2

SHEET 3 of 7

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC (R.Q.D.) (%)	JTS per m	WL & INSTR	q (MPa)	TEST SAMPLE & TYPE	TEST RESULTS
9.30	BEDROCK								
9.45	Begin coring at 9.45m								
1113.9 9.70	CLAYSTONE - olive green - moderately weak - slightly weathered		- 9.48-10.0 some core loss due to slough in the hole	10 (0)					
1113.6 10	SILTSTONE - clayey - medium grey where fresh and olive green where weathered - laminated - moderately weathered - very weak		- 10.20 planar joint, 30°, rough, rust staining 10.21-10.76 3 irregular joints, 80° - 90°, rough, with rust staining	76 (33)	4				
11	sandy, medium grey, laminated, weak, gradational changes from clayey SILTSTONE to very fine grained SANDSTONE		- 11.70;11.86 2 planar joints 85° - 90°, smooth with rust staining		3				
12			- 12.00 planar joint, 10°, rough, rust staining 12.05 breccia zone, 1 cm thick, clay infilling		3				
13	dark greenish grey, slightly weathered, strong		- 12.94 curved joint, 35°, smooth - 13.13 undulating joint, 50° rough - 13.45 soft claystone seam, 1 cm thick, rust staining - 13.60 stepped joint, 10°, rough, rust staining	86 (86)	3				
14					3				
14.65 1108.7 15			- 14.91-15.44 possible shear zone, disturbed	100 (100)	1			0 7	
	CLAYSTONE - greenish grey - laminated - fresh - weak		- 15.65 planar joint, 30°, smooth	100 (88)					
16									

ABBREVIATIONS

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.

Sub-Consultant: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 2

SHEET 4 of 7

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC (R.Q.D.) (%)	JFS per m	WL & INSTR	TEST SAMPLE & TYPE	TEST RESULTS
	CLAYSTONE - dark greenish bluey grey - silty in places - fresh - moderately strong		- 16.08 planar joint, 70°, smooth - 16.22 curved joint, 85°, smooth - 16.37 curved joint, 60°, rough	100	5		D B	
	black		- 16.70 planar contact, 30°, tight - 16.83 curved joint, 60°, rough	(88)				
17	mottled olive brown							
			- 17.58 curved joint, 80°, rough	87	2			
			- 17.80 planar joint, 45°, slickensided, opened by drilling	(72)				
18	SILTSTONE; grading to very fine SANDSTONE, greenish grey, no distinct bedding, fresh, extremely strong, contains limestone pebbles				5			
	blue grey, fresh to slightly weathered		- 18.83 planar bedding joint, ≈ 90°. - 18.84 3 undulating joints, 40°, rough, rust staining	100				
19.01								
1104.3	SANDSTONE - olive brown - silty to fine grained - laminated - moderately weathered - very strong - slightly calcareous - cross-bedded		- 19.25;19.35 2 planar joints, 85°, rough - 19.42-19.85 planar joint, 10°, rough	(95)	3			
20			- 20.15 planar joint, 40°, smooth - 20.36 planar joint, 15°, smooth		4			
20.42								
1102.9			- 20.48-20.95 3 planar bedding joints at 90°, one has rust staining, smooth	100				
	CLAYSTONE - dark grey - laminated - fresh - weak to very weak		- 20.88-21.07 breccia, re-healed	(92)				
21			- 21.24 planar shear, 80°, slickensided		3			
			- 21.60-21.80 breccia, rehealed - 21.84 curved joint, 75°, smooth - 21.92 undulating joint, 15°, rough					
22.00	Grading to SILTSTONE							
1101.3	SILTSTONE - light greenish grey				0			
22.70	Grading to CLAYSTONE			100				
1100.6	CLAYSTONE - light greenish grey - calcareous - fresh - nodules of limestone			(97)				
23								

ABBREVIATIONS

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.

Subconsultant: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 2

SHEET 5 of 7

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	WL & INSTR	C (kPa)	TEST SAMPLE & TYPE	TEST RESULTS
	CLAYSTONE - light greenish grey - fresh		-23.25 irregular joint, 85°, rough -23.38-23.51 shear zone, 80°, rehealed	100	2				
	SILTSTONE; medium greenish grey, laminated, fresh			(97)					
24	dark greenish grey		-24.12 curved joint, 85°, smooth 24.16-24.33 3 planar joints, 70°, smooth						
	Grading to SILTSTONE		-24.57 planar joint, 65°, tight, smooth		6				
	SANDSTONE; light grey, thin to medium bedded, fresh, extremely strong, cross-bedded, coal laminations		-24.75 irregular joint, 65°, rough						
25				100					
	SILTSTONE dark grey to black, laminated, very strong		-25.32 irregular contact, 65°, rough -25.44 planar joint, 65°, tight, smooth 25.48-25.50 shear zone, very thin, polished 25.52;25.62 irregular joints, 80°- 85°, rough	(98)	5				
26			-26.26-26.48 shear zone	100					
			-26.72 planar joint, 75°, rough -26.84-26.98 breccia zone, trace slickensides	(89)	5			D 9	
	SILTSTONE; extremely strong dark grey								
27	SILTSTONE; light greenish grey, fresh, extremely strong								
27.35									
1096	SANDSTONE - light grey - fresh - extremely strong		-27.70 planar joint, 25°, smooth, rust staining	93	1				
28.00				(88)					
	SILTSTONE - greenish grey - fresh - very strong - contains limestone clasts up to 5 mm dia.				1				
28.90			-28.90-29.00 possible core loss						
1094.4	CLAYSTONE - dark grey - laminated - fresh - very strong - slightly calcareous		-29.32 planar shear, 60°, slickensided -29.61 planar shear, 60°, slickensided	93 (93)	2				
30									

ABBREVIATIONS ... WL & INSTR - WATER LEVEL & INSTRUMENTATION

Alberta ENVIRONMENT

OLDMAN RIVER DAM

HOLE No. 85 - 2

SHEET 6 of 7

prime consultant STANLEY ASSOCIATES ENGINEERING LTD.

subconsultant KLOHN LEONOFF LTD.

DRILLHOLE LOG

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	WL & INSTR	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
				93					
			.	(93)					
			- 30.49-30.59 possible core loss		3				
			- 30.75 planar joint, 35°, tight	94					
31	CLAYSTONE - dark grey - laminated - fresh - strong - slightly calcareous - fossil shell fragments			(88)					
			- 31.50 irregular shear, 50°, slickensided, discontinuous - 31.64 joint, 90°, opened by drilling		3				
32									
			- 32.46-32.59 possible core loss		2				
			- 32.81 planar shear, 75°, slickensided - 32.90;33.00 2 planar joints, 85°, rough	100					
33.00									
1090.3	SANDSTONE - light grey - weathering from joints extends into the rock up to 5 cm - extremely strong - cross-bedded complete loss of circulation at 33.5m			(91)					
			- 33.57 planar joint, 25°, smooth, rust staining		3				
34.00									
1089.3	CLAYSTONE - black - becomes greenish grey as silt content increases near 35.0m		- 33.99-34.16 high angle discontinuous shears with slickensides	95			4.0×10^{-4}		
			- 34.34 joint, 50°, slickensided	(95)	1			D 10	
35	greenish grey, with some black veins of CLAYSTONE, appears disturbed and rehealed		- 35.08 curved shear, 80°, rough, slickensided						
			- 35.31-35.36 breccia zone with shearing at 90°						
			- 35.55;35.75 2 irregular joints, 90°, rough	100	6				
				(93)					
			- 35.95 irregular shear, 60°, rough						
36								D 11	
			- 36.62-36.63 breccia zone - 36.82 planar shear, 40°, slickensides - 36.96 planar shear, 85°-90°, slickensides	100 (93)	3		2.7×10^{-4}		
37	greenish grey, increasing silt content								

OBSERVATIONS

WATER LEVEL & INSTRUMENTATION

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD
Sub-Consultant: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 2
SHEET 7 of 7

DEPTH ELEV (-)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC (R.Q.D.) (%)	JTS per m	WL & INSTR	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
	SILTSTONE - greenish grey - clayey - fresh - very strong		37.02 planar joint, 85°, smooth 37.37 planar joint, 35°, smooth,	100	5				
	CLAYSTONE; greenish grey, strong, slightly silty		37.7 2 planar joints, 90°, smooth, opened by drilling	(93)					
38			38.34 stepped joint, 35°, smooth		1				
	extremely strong			100					
39				(100)	0				
40									
40.32									
1083	END OF HOLE @ 40.32m								
41									

ABBREVIATIONS
JTS - JOINTS
CORE REC - CORE RECOVERY
WL & INSTR - WATER LEVEL & INSTRUMENTATION
K - HYDRAULIC CONDUCTIVITY

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.
Subconsultant: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 85 - 28

SHEET 1 of 3

CONTRACTOR(S)/DRILL RIG(S): B: SDS Drilling - Mayhew 1000

RIG No. ____ DEPTH(m) ____ DATE ____ HOLE DIAM. ____ TOP CASING A (El.) ____

RIG No. B DEPTH(m) 20.0 DATE Nov 25 & 26/85 CORE DIAM. 76mm TOP CASING B (El.) ----

LOCATION: HW 13-7-1-W5

COORDINATES: 5491381.1 N
-1440.7 E

INITIAL DIP: VERTICAL

ELEVATIONS: GROUND SURFACE: 1123.3m
ROCK SURFACE: --------
BOTTOM OF HOLE: 1103.3m

DEPTH ELEV. 0.00	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.)	JTS. per m	W.L. & INSTR.	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
1123.3	Triconed to 9.0m								
9.00									
1114.3	SILTSTONE - light brown - completely weathered - clayey							A 1	
9.79	Begin coring at 9.79m								
1113.5 10 10.30	SILTSTONE - light brown - moderately weathered - fractured			100					
1113 11	SANDSTONE - grey - fine grained - medium bedded - fresh jointed - very strong								
12				100					

ABBREVIATIONS:

JTS. - JOINTS
CORE REC. - CORE RECOVERY
R.Q.D. - ROCK QUALITY DESIGNATION
W.L. & INSTR. - WATER LEVEL & INSTRUMENTATION
K - HYDRAULIC CONDUCTIVITY

SUBCONSULTANT:

INSPECTOR:

LOGGED:

APPROVED:

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD
Sub-Consultant: KLOHN LEONOFF LTD

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 85 - 28
SHEET 2 of 3

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC (R.Q.D.) (%)	JTS per m	WL & INSTR	α (c.m/s)	TEST SAMPLE & TYPE	TEST RESULTS
13	SANDSTONE cont'd - grey - fine grained - medium bedded - fresh jointed - very strong								
14									
15									
15.24									
1108.1	SILTSTONE - dark grey - thickly bedded - fresh jointed - strong		- 15.46 1 cm thick clay layer Many slickensided joints					D 2	
16	CLAYSTONE; black, thinly bedded, completely weathered, very weak greenish grey, thinly bedded, completely weathered, very weak slightly weathered, strong								
17	CLAYSTONE; dark grey, thinly bedded, slightly weathered, strong							L.L P.L P.I ϕ'_R	30.6 20.1 10.5 22°-27°
18	slightly weathered, strong completely weathered, very weak							D 4 L.L P.L P.I ϕ'_R	35.5 24.5 11 19°
19	slightly weathered, strong							D 5	

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD

Subconsultant: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 28

SHEET 3 of 3

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	WL & INSTR.	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
	SILTSTONE cont'd - greenish grey - thinly bedded - slightly weathered - strong		- 19.59-20.00 core loss	84					
20.00 1103.3	END OF HOLE @ 20.0m								

ABBREVIATIONS

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD

Subconsultant: KLOHN LEONOFF LTD

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 85 - 3

SHEET 1 of 8

CONTRACTOR(S)/DRILL RIG(S): B: SDS Drilling - Gardner Denver 1700

RIG No. ____ DEPTH(m) ____ DATE ____ HOLE DIAM ____ TOP CASING A (El.) ____

RIG No B DEPTH(m) 44.9 DATE Oct 1-3/85 CORE DIAM 76mm TOP CASING B (El.) ---

LOCATION: NW 13-7-1-W5

COORDINATES: 5491460.0 N

-1525.0 E

INITIAL DIP: VERTICAL

ELEVATIONS: GROUND SURFACE: 1140.9m

ROCK SURFACE: 1127.3m

BOTTOM OF HOLE: 1096.0m

DEPTH / ELEV (m)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE STATE	SAMPLE No.	PENETRATION TEST (Blows/0.15m) D = STANDARD PENETRATION	UNCONFINED COMPRESSION kPa 100 200 300 400 △ / PLASTIC LIMIT — WATER CONTENT — LIQUID LIMIT 10 20 30 40 50%	UNIT WEIGHT kN/m³	COHESION (kPa)	ANGLE OF SHEARING RESISTANCE φ°	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY	PARTICLE SIZE (%)
0.00 / 1140.9												
1	CLAY(CH) - occasional boulder - high plasticity - soft to firm - olive brown			A 1								
2												
3	- firm - dark olive			B 2								
4												

SAMPLE
- undisturbed
- disturbed
- not recovered

(c) natural water content
—S— liquid limit (w_L)
—P— plastic limit (w_P)
△ unconfined compressive strength measured with pocket penetrometer

SAMPLING METHOD
- A split tube
- S shelby tube
- C piston sampler
- D core barrel
- G auger
- T auger

SUBCONSULTANT KLOHN LEONOFF LTD

LOGGED BY JBJ

CHECKED BY TGM

Alberta ENVIRONMENT

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 85 - 3

SHEET 2 of 8

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD

SUBCONSULTANT: KLOHN LEONOFF LTD

DEPTH ELEV (m)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE STATE	SAMPLE No	PENETRATION TEST (Blows/0.15m) ○ - STANDARD PENETRATION	UNCONFINED COMPRESSIVE STRENGTH (kPa)	PLASTIC LIMIT — WATER CONTENT — LIQUID LIMIT	UNIT WEIGHT (kN/m³)	COHESION (kPa)	ANGLE OF SHEARING RESISTANCE ϕ Degrees	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY k (cm/sec)	PARTICLE SIZE (%) Clay & colloids / Silt 0.075–0.002 mm / Sand 4.76–0.075 mm / Gravel over 4.76 mm
	CLAY(CH) - as above Rig B lost circulation, 4.5m												
4.50													
1136 4	SILT(ML) - medium dense - non plastic - dry - light brown			A 3	X X X								
5													
5.50													
1135 4	CLAY(CI-CH) - medium to high plasticity - firm - light brown			B 4									
6													
6.60													
1134 3	GRAVEL(GP-GM) - coarse to fine - cobbles Small water losses occur in this unit.				Refusal								
7													
8													
8.50													
1132 4	CLAY(CI) (TILL) - trace silt - trace fine gravel - medium plasticity - dense - medium to olive brown - massive			A 5	X X X								
9													
10													

SAMPLE

SAMPLING METHOD

Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD
SUBCONSULTANT: KLOHN LEONOFF LTD

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No BS - 3

SHEET 3 of 8

DEPTH ELEV (m)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE STATE	SAMPLE No.	PENETRATION TEST (Blows/0.15m)	UNCONFINED COMPRESSION (kPa)	PLASTIC LIMIT / WATER CONTENT / LIQUID LIMIT (%)	UNIT WEIGHT (kN/m³)	COHESION (kPa)	ANGLE OF SHEARING RESISTANCE (Deg)	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY (cm/sec)	PARTICLE SIZE (%)
10.00													
1130.9	CLAY(CL-CI) (TILL) - silty - some gravel - low to medium plasticity - very dense - dark to medium brown - massive			A 6									
11													
	gravel layer from 11.3m to 11.5m												
12.00													
1128.9	GRAVEL(GM-GC) - silty - coarse to fine				Refusal								
13													
13.60				A 7	40 For 102mm Refusal								
1127.3	CLAYSTONE - silty - dark olive - refer to sheet 4												
14													
15													
16													

SAMPLE

SAMPLING METHOD

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD

Subconsultant: KLOHN LEONOFF LTD

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 3

SHEET 4 of 8

DEPTH (ELEV) (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC (R.Q.D.) (%)	JFS per m	WL & INSTR	q (t/m²)	TEST SAMPLE & TYPE	TEST RESULTS
				100					
13.60	BEDROCK								
1127.3	CLAYSTONE - silty - dark olive			(74)					
14.00	Begin coring at 14.0m								
1126.9	SILTSTONE - light green - moderately weathered		- 14.10 stepped joint, 80°, rough - 14.40 breccia zone - 14.50-15.00 core loss	0	7				
				(0)					
15	olive green, slightly weathered, moderately strong		- 15.21 planar joint, 10°, smooth 15.30-15.53 5 planar joints, 85°- 90°, polished, clay infill - 15.60 planar joint, 10°, smooth 15.70-15.79 2 planar joints, 85°- 90°, polished, clay infill	100 (43)	13				
	clay layer								
16.07			- 16.06 planar shear, 90°, slickensided - 16.19 fault or shear, 75°, clay infill						
1124.8	CLAYSTONE - dark greenish olive - slightly weathered - weak								
	dark bluish black				>25				
	light olive		16.63 high angle shears, 20°, slickensided 16.67-17.24 extremely brecciated and sheared, possible core loss in this interval	84 (0)					
17									
	dark grey		17.24-18.00 about 20 joints, mostly 65°- 85°, moderately weathered, trace of slickensides, brecciated		>25				
18	becoming dark reddish brown, and becoming siltier		- 18.00-18.36 6 planar joints, 80°- 90°, slightly weathered						
18.25									
1122.7	SILTSTONE - light grey - slightly weathered - strong - oxidized to 19.15m			100 (84)	10				
19			- 18.81 planar joint, 75°, smooth, slightly weathered 18.93 planar joint, 45°, smooth, slightly weathered						
	thin CLAYSTONE bed		- 19.44 planar joint, 3°, smooth		10				
20			19.90 planar joint, 1°, - water loss while drilling						

ABBREVIATIONS ...

Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD
SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 3
SHEET 5 of 8

DEPTH (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC (R.Q.D.) (%)	JTS per m	WL & INSTR	k (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
	thin CLAYSTONE bed			100					
	SILTSTONE cont'd - light grey - slightly weathered - strong			(84)	4				
			- 20.61 planar joint, 50°, smooth - 20.78 curved joint, 70° - 80° rough						
	grading to SANDSTONE		20.83 planar joint, 25°, rough	94					
21				(79)					
	SANDSTONE; light grey, fine grained, slightly weathered, very strong		- 21.31;21.66;21.96 3 planar joints, 80° - 90°, rough 21.40;21.75; 2 planar joints 20° - 25°, very rough - 21.58;22.00;22.15;22.27 4 planar joints, 45° - 60°, rough		7				
	dark grey, slightly weathered,								
22									
22.50					6				
1113.4	CLAYSTONE - dark blackish grey - slightly weathered - moderately weak to strong		- 22.65-22.75 3 planar joints, 40°, smooth						
				92					
23			- 23.15;23.58;23.64 3 planar joints, 60° - 70°, rough 23.25;23.28;23.40;23.77 4 irregular joints, 80° - 90° rough	(82)	7				
24									
			- 24.25 undulating joint, 0°, rough, manganese staining - 24.40;24.55;24.77;25.08 4 joints, 70° - 90°, oxide staining		5				
	dark greenish grey, laminated, very strong								
			- 24.90 planar joint, 0°, smooth, rust staining	100					
25				(96)					
			- 25.58;25.77;25.88 3 planar joints, 80° - 90°, smooth		4				
26			- 26.00 irregular joint, 0°, rough, rust staining - 26.14 planar joint, 90°, smooth, manganese staining - 26.45 planar joint, 0°, rough, rust staining						
			26.50-27.00 sheared and broken, possibly some core loss in this interval	73	4				
	rust staining on joints, very weak			(25)					
27									

ABBREVIATIONS

Alberta ENVIRONMENT

OLDMAN RIVER DAM

DRILLHOLE LOG

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.
Subconsultant: KLOHN LEONOFF LTD.

HOLE No. 85 - ;
SHEET 6 of 8

DEPTH ELEV (-)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC (RQD) (%)	JFS per m	WL & INSTR	k (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
	CLAYSTONE cont'd - dark greenish grey - slightly weathered - rust staining on joints - very weak		Many joints but core is very disturbed, rust staining on joint surfaces. Trace clay gouge.	73 (25)	>25			D C	
28.00									
1112.9	SILTSTONE - medium grey where fresh - olive in weathered zones - laminated - moderately weathered - very strong - cross-bedded		- 28.10 planar joint, 30°, rough - 28.20;28.30;28.40 3 planar joints, 30°- 90°, rough, manganese staining 28.40;28.41 2 irregular joints, 40°- 50°, smooth, rust staining		8				
29			- 28.91 planar joint, 30°, rough, rust staining	100					
29.25			- 29.14 planar joint, 55°, smooth, rust staining	(100)					
1111.7	SANDSTONE - fine to medium grained - moderately weathered - extremely strong - calcareous		- 29.41 planar joint, 35°, smooth, rusty Bedding trace at 75°. - 29.69 shearing on contact, 75°, slickensided		6			D S	
29.69									
1111.2	CLAYSTONE - silty - dark blackish grey - slightly weathered - weak		- 29.94 breccia zone, 50° - 30.12-30.20 breccia zone, slickensided Some core loss near 30.90		3			M.C L.L P.L P.I D 10	6.5 60.7 23.6 17.1
30									
	becoming medium greenish grey, mottled with rust on laminations, laminated		- 30.90 irregular shear, 80°, rough, slightly weathered, clay gouge, high plastic. - 31.43;31.65;31.81 3 planar joints, 80°- 85°, rough, rust staining	100 (100)	4			D 11	
31									
32			- 31.85-32.00 sheared and rehealed, high angle, discontinuous 32.10-32.24 2 bedding joints 80°						
32.40									
1108.5	SILTSTONE - medium greenish grey - laminated - fresh - strong				2				
33				100					
33.20			- 33.20-33.22 brecciated - 33.32-33.34 brecciated - 33.40-33.41 brecciated	(92)					
1107.7	CLAYSTONE - dark greenish grey - laminated - fresh - weak - breaks on rehealed shears		- 33.60 planar shear, 80°, slickensided - 33.70 planar shear, 80°, slickensided		5				
34									

ABBREVIATIONS JFS - JOINTS WL & INSTR - WATER LEVEL & INSTRUMENTATION

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD
Subconsultant: KLOHN LEONOFF LTD

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No BS - 3
SHEET 7 of 8

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC (RQD) (%)	JFS per m	WL & INSTR	q (m/s)	TEST SAMPLE & TYPE	TEST RESULTS
	CLAYSTONE cont'd becoming siltier, trace of limestone pebbles								
34.8			34.30 planar joint, 0°, rough, rusty	100	2				
1104.5	SANDSTONE - very fine grained - moderately weathered - extremely strong			(92)					
35	medium grey, thickly bedded, black coal laminations on cross-bedding		34.90 planar joint, 20°, rough, tight		0				
35.90									
1105	CLAYSTONE - dark greenish grey - laminated - fresh - strong		36.03-36.33 breccia zone disturbed by drilling action						
			36.39-36.42 breccia zone with shears	92	1				
				(74)					
37	black		37.23 irregular shear, 50°, slickensided 37.23-37.53 disturbed, rehealed 37.60 irregular shear, 25°, slickensided 37.77-38.00 possible core loss in this zone		2				
38	siltier		38.25 planar joint, 20°, rough	100	1				
				(88)					
39	SILTSTONE; dark greenish grey, no visible bedding, fresh, very strong								
	dark greenish grey, laminated, fresh, strong		39.60-39.63 breccia zone 39.70 stepped joint, 70°, smooth		1				
39.80									
1101.1									
40	SILTSTONE - greenish olive grey - fresh - strong - clayey in some zones		40.04 stepped joint, 40°, rough, slightly weathered 40.10 planar joint, 30°, rough, opened by drilling	100					
				(100)					
40.91			40.91 irregular contact, 90°, smooth						
1100	CLAYSTONE								

ABBREVIATIONS
JFS - JOINTS
WL & INSTR - WATER LEVEL & INSTRUMENTATION

Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD
SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 3
SHEET 8 of 8

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC (R.Q.D.) (%)	JTS per m	WL & INSTR	q (m/s)	TEST: SAMPLE & TYPE	TEST: RESULTS
	CLAYSTONE cont'd - dark greenish grey - fresh - strong			100 (100)	1				
41.70			- 41.67 possible shear, 85°, rough						
1099.2 42	SILTSTONE - dark greenish grey - fresh - strong		- 42.00 planar joint, 70°, smooth 42.10 planar joint, 30°, smooth 42.27 planar joint, 13°, smooth	100 (100)	4				
42.50									
1098.4 43	SANDSTONE - greenish grey - fine to medium grained - fresh - very strong - trace coal laminations			97	3				
43.83	grading to SILTSTONE		- 43.65 planar joint, 50°, smooth, opened by drilling	(87)					
1097.1 44	CLAYSTONE - dark greenish grey - fresh - moderately strong		Bedding 80° TCA 44.69-44.79 4 planar joints, 80°, smooth, drilling breaks on bedding - 44.83 brecciated and sheared		5				
44.90									
1096 46	END OF HOLE @ 44.90m								

ABBREVIATIONS
JTS - JOINTS
WL & INSTR - WATER LEVEL & INSTRUMENTATION

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD
Subconsultant: KLOHN LEONOFF LTD

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 85 - 4

SHEET 1 of 5

CONTRACTOR(S)/DRILL RIG(S) A: Dwyre Construction - Mitsubishi 230 LC, B: SDS Drilling - Gardner Denver 1700

RIG No. A DEPTH(m) 4.0 DATE Nov 16/85 HOLE DIAM Test Pit TOP CASING A (El.) --

RIG No. B DEPTH(m) 30.0 DATE Nov 11-14/85 CORE DIAM 76mm TOP CASING B (El.) 1097.9

LOCATION: NW 13-7-1-W5

COORDINATES: 5491206.1 N
-1360.2 E

INITIAL DIP: VERTICAL

ELEVATIONS GROUND SURFACE 1097.8m
ROCK SURFACE: 1093.3m
BOTTOM OF HOLE: 1067.8m

DEPTH ELEV (m)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE STATE	SAMPLE No.	PENETRATION TEST (Blows/0.15m) S - STANDARD PENETRATION	UNCONFINED COMPRESSION kPa (100 200 300 400)	PLASTIC LIMIT / WATER CONTENT / LIQUID LIMIT (10 20 30 40 50 60 70 80 90 %)	UNIT WEIGHT (kN/m³)	COHESION (kPa)	ANGLE OF SHEARING RESISTANCE Ø' Deg.	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY (cm/sec)	PARTICLE SIZE (%) Clay & Silt / Sand / Gravel / Cobbles & Boulders
0.00													
1097.8	SILT(ML) - some sand - trace roots												
0.40													
1097.4	SAND AND GRAVEL(GW) - coarse to fine - gravel to 75mm - trace silt												
0.80													
1097													
1	SAND(SP) - fine grained - little silt												
2.00													
1095.8	SAND AND GRAVEL(GW) - coarse to fine - gravel to 75mm - trace silt												
2.60													
1095.2													
3	GRAVEL(GP) - coarse - frequent cobbles up to 200 mm - occasional boulders - little sand - clean										Dec 1/85 Jan 11/86 Test Pit Nov 16/85		
4													

SAMPLE
- Undisturbed
- Disturbed
- Not recovered

- Natural water content (w)
- Liquid limit (w_L)
- Plastic limit (w_P)
- Unconfined compressive strength measured with pocket penetrometer

SAMPLING METHOD
A - Split tube
B - Shelby tube
C - Piston sampler
D - Core barrel
E - Auger
F - Wash

SUBCONSULTANT KLOHN LEONOFF LTD

LOGGED BY [illegible]

APPROVED [illegible]

Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD
SUBCONSULTANT: KLOHN LEONOFF LTD

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 85 - 4
SHEET 2 of 5

DEPTH (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC (TCR) (RQD) (%)	JTS per m	WL & INSTR	K (m/s)	TEST SAMPLE & TYPE	TEST RESULTS
	GRAVEL (GP) - as above								
4.50	BEDROCK								
1093.3									
	SILTSTONE								
5									
6									
6.40	Begin coring at 6.4m								
1091.4	SILTSTONE - medium greenish grey - thickly bedded - fresh - strong			100	1				
7			- 6.90-6.99 planar shear, 80°, clay and silt infill, brecciated	(91)					
	Grading to SANDSTONE		- 7.30 planar joint, 85°, very rough						
7.50			- 7.50 planar joint, 55°, rough, rust stained		7				
1090.3			- 7.59-8.32 7 planar joints, 70°-85°, rough, weathered surfaces	96					
8	SANDSTONE - medium grey - salt and pepper texture - fine to medium grained - medium bedded - slightly weathered - strong		Bedding 80° TCA	(71)	3				
			- 8.72 planar joint, 70°, rough, moderately weathered						
9			- 9.20 2 planar joints, 70°, 50°, rough, weathered	69	6				
			- 9.40 planar joint, 5°, moderately weathered	(51)					
			- 9.62-9.70 3 planar joints, 30°- 35°, rough						
9.70			- 9.78-10.50 slickensided surfaces						
1088.1									
10	CLAYSTONE - dark greenish-grey - thickly bedded - moderately weathered - weak		10.10 planar shear, 55°, slickensides	66	1			D 1	
			- 10.50-11.20 possible core loss, probably claystone	(59)					
11									

ABBREVIATIONS
JTS - JOINTS
WL & INSTR - WATER LEVEL & INSTRUMENTATION

Alberta ENVIRONMENT

prime consultant: STANLEY ASSOCIATES ENGINEERING LTD.
subconsultant: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 4
SHEET 3 of 5

DEPTH (ELEV) (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC (N.Q.D.) (%)	JTS per m	WL & INSTR	q (L/m/m)	TEST SAMPLE & TYPE	TEST RESULTS
	CLAYSTONE - dark green - thickly bedded - moderately weathered - weak			66 (59)	1				
12			-11.96-12.16 3 planar joints, 70°-75°, smooth						
			-12.41;12.60 2 planar shears, 60°, slickensided	100 (80)	6			D 2	
	grading to SILTSTONE								
12.95			-12.88;12.92 2 planar joints, 70°- 80°, smooth						
1084.9	SANDSTONE - medium grey - strong - fine grained								
13.35	- slightly weathered								
1084.5			-13.61 planar joint, 70°, smooth	100 (77)	3				
	SILTSTONE - dark greenish grey - medium bedded - slightly weathered - strong								
14			-14.28 curved joint, 0°- 15°, smooth	100 (71)	7				
15			-14.96 planar joint, 60°, smooth						
15.20									
1082.6	SANDSTONE - medium grey - medium grained - thickly bedded - slightly weathered - strong to very strong		-15.32;15.35 2 curved joints, 70°- 85°, smooth						
			-15.60 curved joint, 10°-90°, rough		7				
16	coarse grained		-16.04 planar joint, 50°, smooth						
			16.07;16.28 2 planar joints at 90°, smooth						
			Bedding 80° TCA	95 (94)	3				
17									
	grading to SILTSTONE								
17.40			-17.50 planar joint, [illegible], smooth		2				
1080.2	CLAYSTONE - dark greenish grey - moderately slightly weathered strong		-17.75 planar joint, [illegible], smooth						
18									

ABBREVIATIONS: JTS JOINTS; WL & INSTR WATER LEVEL & INSTRUMENTATION

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD
Subconsultant: KLOHN LEONOFF LTD

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 85 - 5
SHEET 4 of 5

DEPTH (ELEV) (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC (ROD) (%)	JTS per m	WL & INSTR	α (+/-/-)	TEST SAMPLE & TYPE	TEST RESULTS
	CLAYSTONE cont'd								
18.30	grading to SILTSTONE								
1079.5	SANDSTONE - medium grey - very thinly bedded - salt and pepper texture - slightly weathered		18.27 curved joint, 50°- 90°, smooth 18.35 planar joint, 15°, rough	97	7				
			18.75 curved joint, 65°- 80°, smooth 18.90 curved joint, 0°- 50°, smooth	(80)					
19.05	SILTSTONE; dark greenish grey, strong								
1078.8	CLAYSTONE - greenish-grey - medium bedded - moderately weathered - moderately weak - bedding dips at 15°		19.30 planar shear, 60°, slickensided 19.50-19.60 broken by drilling, slickensided fragments 19.89 planar shear, 55°, slickensided		4			D 3	
20			20.04 planar shear, 70°, slickensided 20.12 planar shear, 55°, slickensided					D 4	
	moderately strong to strong		20.50 planar shear, 45°, slickensided 20.54;20.56 2 planar joints, 75°, smooth	100 (79)	9				
21			20.88 planar joint, 60°, smooth						
21.50									
1076.3					7				
22			21.90 curved joint, 0°- 45°, smooth						
			22.38 planar joint, 45°, smooth 22.50-24.20 core loss in this interval	20	3				
	SILTSTONE - grey			(20)					
23	- medium bedded - moderately weathered - strong								
24									
			24.34 planar joint, 70°, rough 24.45 planar joint, 80°, rough	82 (80)	6				
24.70									
1073.1	SANDSTONE - light grey - thinly bedded								

ABBREVIATIONS: JTS JOINTS; WL & INSTR WATER LEVEL & INSTRUMENTATION

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD
Subconsultant: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 4
SHEET 5 of 5

DEPTH ELEV (-)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC (R.Q.D) (%)	JTS per m	WL & INSTR	r (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
	SANDSTONE - light grey - thinly bedded - medium grained - slightly weathered - very strong		- 25.25-25.77 5 planar fractures, drill induced, 85° - 90°, tight, rough to very rough	92 (80)	6				
25.90 1071.9	SILTSTONE - dark grey - medium bedded - moderately weathered - strong		- 25.90 planar contact, 90°, smooth - 26.01-27.08 6 fractures, drill induced, 85° - 90°, tight						
26.40 1071.4	SANDSTONE - light grey - coarse grained - salt and pepper texture - thinly bedded			100 (75)	5				
27	- fresh - very strong		Bedding plane trace at 85° TCA						
	thin CLAYSTONE seam, 2 cm thick		- 27.26-27.68 6 planar joints, 80° - 90°, smooth - 27.42 planar joint, 10°, rough		13				
28	CLAYSTONE; black, very thinly bedded, fresh, weak		- 27.83;27.85 2 planar joints, 70°, smooth, trace of clay infilling					D S	
	fine grained			100 (96)	0				
29									
29.40 1068.4	SILTSTONE - medium to dark grey - slightly weathered - very strong		- 29.33 planar joint, 90°, smooth - 29.65;29.75;29.82 3 joints planar 85° - 90°, drill induced		4				
30.00 1067.8	END OF HOLE @ 30.00m								

ABBREVIATIONS

JTS = JOINTS

WL & INSTR = WATER LEVEL & INSTRUMENTATION

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.

Subconsultant: KLOHN LEONOFF LTD

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 85 - 5

SHEET 1 of 5

CONTRACTOR(S)/DRILL RIG(S): A: Dwyre Construction - Mitsubishi 230 LC; B: SDS Drilling - Gardner Denver 1700

RIG No. A DEPTH(m) 4.0 DATE Nov 16/85 HOLE DIAM Test Pit TOP CASING A (El.) -------

RIG No. B DEPTH(m) 30.0 DATE Nov 14-15/85 CORE DIAM 76mm TOP CASING B (El.) -------

LOCATION: NW 13-7-1-W5

COORDINATES: 5491293.9 N

-1307.1 E

INITIAL DIP: VERTICAL

ELEVATIONS: GROUND SURFACE: 1097.4m

ROCK SURFACE: 1094.0m

BOTTOM OF HOLE: 1067.4m

DEPTH ELEV (m)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE STATE	SAMPLE No.	PENETRATION TEST (Blows/0.15m) - S - STANDARD PENETRATION	UNCONFINED COMPRESSION kPa (100 200 300 400) PLASTIC LIMIT / WATER CONTENT / LIQUID LIMIT (10 20 30 70 90%)	UNIT WEIGHT kN/m³	COHESION (kPa)	ANGLE OF SHEARING RESISTANCE φ' (Deg)	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY (cm/sec)	PARTICLE SIZE (%) CLAY < 0.002mm / SILT 0.002 - 0.06mm / SAND 0.06 - 2mm / GRAVEL 2 - 75mm
0.00												
1097 0.15	TOPSOIL		4									
1097	GRAVEL(GP) - coarse to fine - frequent cobbles - occasional boulders - little sand - clean - seepage at bedrock surface		3									
3.40	BEDROCK											
1094	SILTSTONE - refer to sheet 2											
4												

SAMPLE
- UNDISTURBED
- DISTURBED
- NOT RECOVERED

- NATURAL WATER CONTENT (w)
- LIQUID LIMIT (w_L)
- PLASTIC LIMIT (w_p)
- UNCONFINED COMPRESSIVE STRENGTH MEASURED WITH POCKET PENETROMETER

SAMPLING METHOD
- A - SPLIT TUBE
- B - SHELBY TUBE
- C - PISTON SAMPLER
- D - CORE BARREL
- G - AUGER
- W - WASH

SUBCONSULTANT KLOHN LEONOFF LTD

LOGGED BY: TKM

APPROVED TKM

DATE

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD
Subconsultant: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 5
SHEET 2 of 5

DEPTH ELEV (-)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC (ROD) (%)	JTS per m	WL & INSTR	k (m/s)	TEST SAMPLE & TYPE	TEST RESULTS
3.40	BEDROCK								
1094	SILTSTONE - clayey - brown becoming grey with oxidized fractures at 4.0m - severely weathered and friable								
4									
5.00									
1092	4 CLAYSTONE								
6									
6.30	Begin coring at 6.3m								
1091	1 CLAYSTONE - medium to dark greenish grey - thickly bedded - slightly weathered - moderately strong		6.35 planar joint, 10°, rough, moderately weathered	100 (72)	1				
7								D 2	
	weak to moderately strong		7.55 planar shear, 75°, smooth 7.64 planar shear, 50°, slickensides 7.71 planar shear, 75°, smooth, breccia infill 7.55-8.13 shear zone, rehealed high angle slickensides 8.07;8.10 2 planar joints, 85°, very rough 8.14 planar joint, 60°, very rough 8.37 planar joint, 70°, rough	100 (78)	4			D 3 D 4	
8									
	SILTSTONE, greenish grey, medium bedded, fresh, strong to very strong				5				
9				77 (74)	2				
			9.46 planar joint, 85°, smooth 9.50 planar joint, 75°, smooth, trace of clay infilling						
10									

ABBREVIATIONS
JTS - JOINTS
CORE REC - CORE RECOVERY
WL & INSTR - WATER LEVEL & INSTRUMENTATION
k - HYDRAULIC CONDUCTIVITY

Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD.
SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 5
SHEET 3 of 5

DEPTH (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JFS per m	WL & INSTR	k (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
			- 10.26 planar shear, 60°, slickensided, moderately narrow with breccia infill	95 (93)	4				
11			- 10.96 planar joint, 70°, smooth, trace clay infill		3				
			- 11.75-11.90 possible core loss						
12	CLAYSTONE - medium greenish grey - thickly bedded - fresh - strong		- 12.11 planar joint, 60°, smooth - 12.42;12.58;12.64 3 planar joints, 85° - 90°, tight	93 (79)	5				
13			- 13.22 planar shear, 70°, slickensides, moderately wide with clay gouge and claystone breccia infilling		7			D 5	
			- 13.75-13.90 possible core loss						
14			- 14.22 planar joint, 40°, smooth - 14.39-14.50 sheared and brecciated - 14.64;14.68 2 planar joints, 80°, smooth	68 (51)	7				
14.80			- 14.80 planar contact at 85° rough						
1082.6	SANDSTONE - medium to dark grey - medium bedded - medium grained - fresh - strong		Bedding plane trace at 75° TCA						
15									
15.30			- 15.30-16.00 possible core loss		0				
1082.1	CLAYSTONE - medium to dark greenish grey - thickly bedded - slightly weathered - weak								
16				100 (95)	2				
			- 16.70-16.90 high angle slickensides						
17								D 5	

ABBREVIATIONS: JFS - JOINTS; WL & INSTR - WATER LEVEL & INSTRUMENTATION; k - HYDRAULIC CONDUCTIVITY

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD

Subconsultant: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 85 - 5

SHEET 4 of 5

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC (R.Q.D.) (%)	JTS per m	WL & INSTR	k (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
	CLAYSTONE - medium to dark greenish grey - thickly bedded - slightly weathered - weak		- 17.11-18.07 11 fractures, 80°- 90°, drill induced	100 (58)	0				
18.00 1079.4	siltier SANDSTONE - medium grey - fine to medium grained - thickly bedded - fresh - very strong		Bedding plane trace at 85° TCA - 18.62-18.86 3 fractures, 75°- 80°, drill induced	100 (96)	0				
19	fossiliferous		- 19.30 planar joint, 15°, rough		1				
20			- 20.06 planar joint, 90°, rough	100 (100)	1				
21			- 20.87-21.88 6 planar fractures, 85°- 90°, drill induced		0				
22	medium greenish grey, thickly bedded, fine grained		Bedding plane trace at 85° TCA - 22.34-22.68 3 fractures, 80°- 85°, drill induced	100 (93)	0				
23			- 23.02-23.07 3 planar joints, 85°, smooth - 23.30 stepped joint, 90°, rough		4				
21.60 1073.8 24	CLAYSTONE - dark greenish grey - moderately strong - medium bedded - slightly weathered		- 23.60-24.00 slickensided surfaces,- high angle slickensides						

ABBREVIATIONS:
JTS - JOINTS
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Alberta ENVIRONMENT

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SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 5
SHEET 5 of 5

DEPTH ELEV (-)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC (R.Q.D.) (%)	JTS per m	WL & INSTR.	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
	CLAYSTONE - dark greenish grey - medium bedded - slightly weathered - moderately strong		- 24.13 joint, 70°, open 24.00-25.00 high angle slickensides						
			- 24.58-24.67 3 planar joints 80°, smooth	100 (88)	4			D 7	
25	fossil shells								
			- 25.51 curved joint, 30°- 90° rough		5				
			- 25.76 planar joint, 35°, smooth						
26									
26.43			- 26.16 planar shear, 80°, slickensided, moderately wide with breccia infill - 26.25 planar shear, 75°, slickensided 26.43 planar contact at 80°						
1071	SILTSTONE - medium grey - medium bedded - fresh - strong			100 (89)	7			D 8	
27									
27.70			- 27.46 planar joint, 55°, rough		2				
1069	7		- 27.70 planar contact, 80°, rough						
28	SANDSTONE - light grey - medium bedded - medium grained - fresh - very strong		Bedding plane trace at 75° TCA						
			- 28.57 planar joint, 35°, smooth		2				
	coarse grained, cross-bedded		- 28.72 bedding joint, 85°, tight	100 (90)					
29	trace clay lumps								
			- 29.49;29.54 2 planar joints 75°, rough, moderately weathered		2				
30.00									
1067	4 END OF HOLE 30.0m								

ABBREVIATIONS
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CORE REC - CORE RECOVERY
WL & INSTR - WATER LEVEL & INSTRUMENTATION
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Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.
Subconsultant: KLOHN LEONOFF LTD

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 85 - [illegible]

SHEET 1 of 9

CONTRACTOR(S)/DRILL RIG(S): A: Chilako Drilling - ML 1050 Auger; B: SDS Drilling - Mayhew 1000

RIG No. A DEPTH(m) 13.4 DATE Sep 5/85 HOLE DIAM 140mm TOP CASING A (El.) 1135.6m

RIG No. B DEPTH(m) 50.0 DATE Sep 27-29/85 CORE DIAM 76mm TOP CASING B (El.) 1135.4m

LOCATION: SW 13-7-1-W5

COORDINATES: 5491198.8 N
-1222.3 E

INITIAL DIP: VERTICAL

ELEVATIONS: GROUND SURFACE: 1135.0m
ROCK SURFACE: 1122.8m
BOTTOM OF HOLE: 1085.0m

DEPTH ELEV (m)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE STATE	SAMPLE No.	PENETRATION TEST (Blows/0.15m) S - STANDARD PENETRATION	UNCONFINED COMPRESSION kPa	PLASTIC LIMIT / WATER CONTENT / LIQUID LIMIT	UNIT WEIGHT (kN/m³)	COHESION (kPa)	ANGLE OF SHEARING RESISTANCE Ø°	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY (cm/sec)	PARTICLE SIZE (%)
0.00													
1135.0 0.20	TOPSOIL												
1134.8 0.90	SILT(ML) - little sand - dry - brown												
1134.1 2 2.40	GRAVEL(GM) - fine to coarse - some silt - some sand - sub-angular to sub-rounded - brown		A	1									
			A	2	Refusal								
1132.6 3	CLAY(CI) (TILL) - silty - little to some sand - little gravel - carbon specks - medium plasticity - hard - brown - massive		B	3									
			A	4									

SAMPLE
- UNDISTURBED
- DISTURBED
- NOT RECOVERED

- ⊙ NATURAL WATER CONTENT (%)
- —K— LIQUID LIMIT (%)
- —X— PLASTIC LIMIT (%)
- △ UNCONFINED COMPRESSIVE STRENGTH MEASURED WITH POCKET PENETROMETER

SAMPLING METHOD
A - SPLIT TUBE
B - SHELBY TUBE
C - PISTON SAMPLER
D - CORE BARREL
E - AUGER
F - WASH

SUBCONSULTANT KLOHN LEONOFF LTD

LOGGED BY: TKM/IT

APPROVED TKM

Alberta ENVIRONMENT

prime consultant: STANLEY ASSOCIATES ENGINEERING LTD

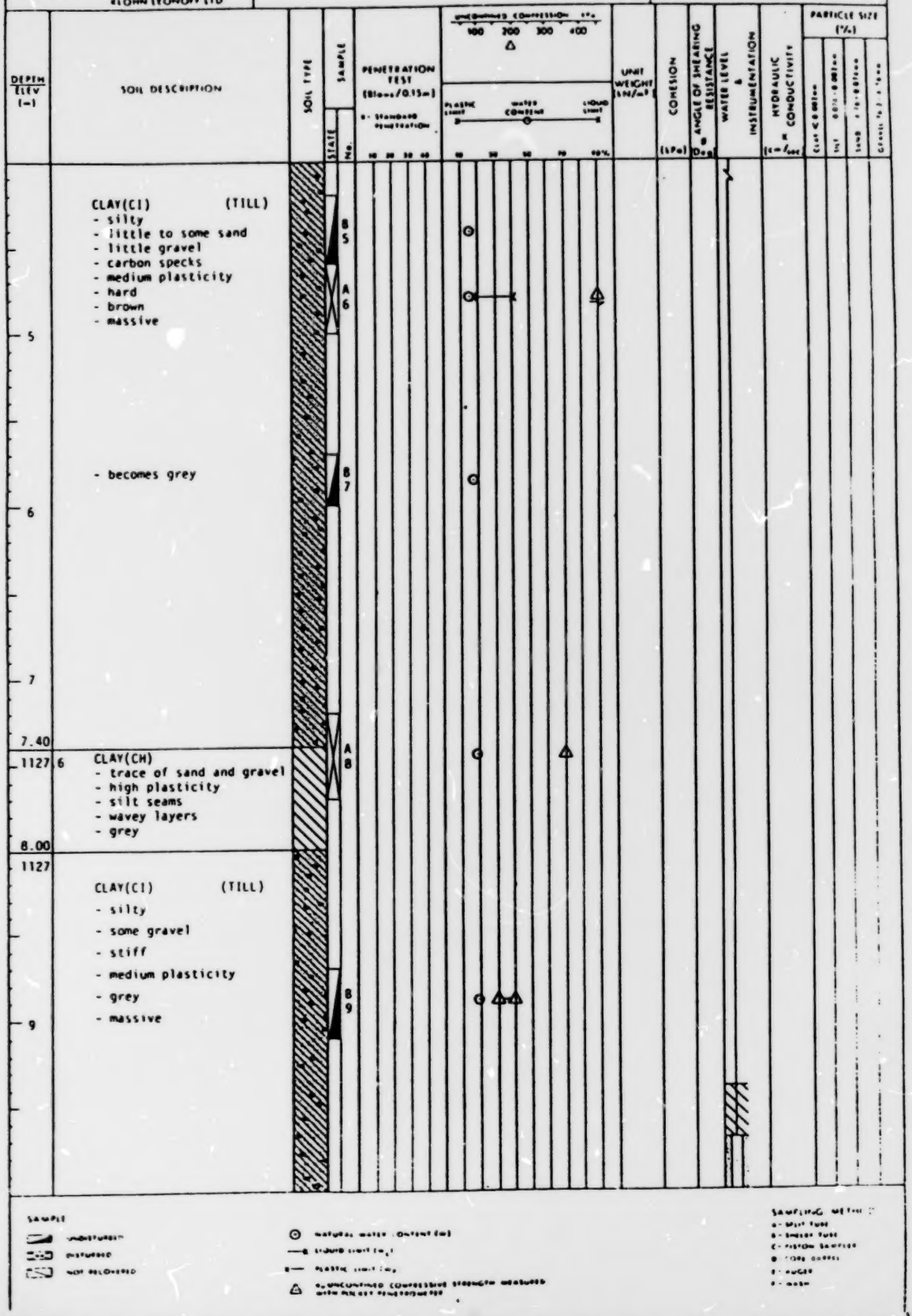
subconsultant: KLOHN LEONOFF LTD

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 85 - 6

SHEET 2 of 9



SAMPLE

- undisturbed
- disturbed
- not recovered

- natural water content (w)
- liquid limit (w_L)
- plastic limit (w_p)
- unconfined compressive strength measured with pocket penetrometer

SAMPLING METHOD

- A - Split Tube
- B - Shelby Tube
- C - Piston Sampler
- D - Core Barrel
- E - Auger
- F - Wash

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD
Subconsultant: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 85 - 6

SHEET 3 of 9

DEPTH ELEV (m)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE STATE	SAMPLE No.	PENETRATION TEST (Blows/0.15m) ● - STANDARD PENETRATION	UNCONFINED COMPRESSION kPa 100 200 300 400 △	PLASTIC LIMIT / WATER CONTENT / LIQUID LIMIT 10 20 30 40 70 90%	UNIT WEIGHT kN/m³	COHESION (kPa)	ANGLE OF SHEARING RESISTANCE ϕ Deg	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY K cm/sec	PARTICLE SIZE (%) Clay <0.002mm · Silt 0.002–0.06mm · Sand 0.06–2.00mm · Gravel >2.00mm
11	CLAY(CI) (TILL) - silty - some gravel - hard - medium plasticity - grey - massive			A 10							Slot-ted pipe		
12													
12.20													
1122.8	CLAYSTONE			A 11									
				A 12							Dry Sep 28/85 Dry Jan 11/86		
13	- refer to sheet 4												
				A 13	32 For 50mm								
14													

SAMPLE
- undisturbed
- disturbed
- soil recovered

- ⊙ natural water content (w)
- —● liquid limit (w_L)
- ●— plastic limit (w_p)
- △ q_u unconfined compressive strength obtained with pocket penetrometer

SAMPLING METHOD
A - Split Tube
B - Shelby Tube
C - Piston Sampler
D - Core Barrel
E - Auger
F - Wash

Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD.
SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 6
SHEET 4 of 9

DEPTH / ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC (R.Q.D.) (%)	JTS per m	WL & INSTR	k (m/s)	TEST SAMPLE & TYPE	TEST RESULTS
12.20 / 1122.8	BEDROCK								
12.45 / 1122.6	Begin coring at 12.45m			100 (100)					
13	CLAYSTONE - dark olive grey - trace maroon colouring - thickly bedded - slightly weathered - weak		Rock is broken from drilling and handling. No visible natural discontinuity other than intense brecciation. Oxide staining on brecciated surfaces.	100 (100)	0			M.C L.L P.L P.I D	14.2 39.1 24.2 14.9 14
14	SILTSTONE; medium grey, medium bedded, fresh, strong		14.34 irregular joint, 70°, rough 14.49 irregular joint, 80°, rough Many drill breaks on bedding planes, 90°, TCA	100 (49)	2				
15	dark grey, thickly bedded, fresh, weak		No natural discontinuities observed. Rock is broken up from drilling and handling. Most breaks are 90° TCA	100 (100)	0				
16	SILTSTONE; light greenish grey, thickly bedded, fresh, weak to very weak				0				
17	medium bedded, fresh, weak		17.15;17.18;17.22;17.25; 17.38;17.44 6 bedding joints 90°, rough 17.48-17.64 brecciated	100 (70)	6			M.C D	22.8 15
18.02 / 1117	SILTSTONE - clayey - greenish grey - thickly bedded - fresh - very stiff to weak CLAYSTONE; dark greenish grey		18.50-18.64 brecciated 18.55-18.60 many fine joints, 65°, unopened	100 (87)	25				
19									

ABBREVIATIONS: JTS - JOINTS; WL & INSTR - WATER LEVEL & INSTRUMENTATION

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD
Subconsultant: KLOHN LEONOFF LTD

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 6
SHEET 5 of 9

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC (R.Q.D.) (%)	JTS per m	WL & INSTR	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
	SILTSTONE - clayey - greenish grey - thickly bedded - fresh - very weak to firm			100 (87)	0			M.C	13.1
	CLAYSTONE; dark blackish grey, fresh, weak								
	SILTSTONE; greenish grey		- 19.90-20.00 highly brecciated and slickensided						
20	CLAYSTONE; dark blackish grey, fresh, weak, brecciated		- 20.02 undulating joint, 55°, slickensided - 20.20 stepped joint, 60°, slickensided					D 16	
	dark greenish grey, weak		- 20.59 undulating joint, 45°, slickensided	100 (92)	4				
21			- 21.00 irregular joint, 90°, rough						
			- 21.61 planar joint, 5°, rough 21.60-22.24 5 undulating joints, 90°, rough, some with rust staining		4				
22	dark grey, thickly bedded, rust staining on joint surfaces, moderately strong		- 22.13 undulating joint, 60°, rough, rust stained - 22.35 joint, 50°, rust stained - 22.42 joint, 75°, rust stained - 22.55 joint, 20°, rust stained - 22.64 joint, 75°, rust stained - 22.66 joint, 55°, rust stained 22.76;22.86;22.94 3 joints 85°- 90°, one has rust staining	100 (75)	11				
22.90									
1112.1				100 (99)	0				
24	SANDSTONE - medium to dark grey - very fine to fine grained - thickly bedded - fresh - extremely strong		Bedding plane trace at 80° TCA - 24.30 planar joint, 50°, rough		3				
			- 24.92;24.94 2 planar joints, 55°- 60°, rough - 25.06 planar joint, 90°, rough	100 (99)	2	Pz B ▼ Oct 1/85 Pz B ▼ Jan 11/86 Pz B ▼ Nov 7/85			
25									
26			- 25.87 planar joint, 80°, rough						

ABBREVIATIONS: JTS - JOINTS
WL & INSTR - WATER LEVEL & INSTRUMENTATION
K - HYDRAULIC CONDUCTIVITY

Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD.
SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 6
SHEET 6 of 9

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	W.L. & INSTR.	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
				100 (100)	3				
			- 26.68 joint, 55°, tight						
27			26.52-27.70 6 planar joints, 75° - 85°, rough						
	SANDSTONE - medium to dark grey - very fine to fine grained - very thickly bedded - fresh - extremely strong				9				
			- 27.74-28.94 9 joints, 80° - 90°, tight, bedding fractures	100 (78)	5				
28									
			- 28.98 planar joint, 60°, rough						
29			- 29.12 planar joint, 85°, rough						
			- 29.47 planar joint, 85°, rough	100 (79)	2				
30									
	CLAYSTONE; blackish grey, weak dark grey, fine to medium grained		- 30.21 contact, 80°, rust stained - 30.30 irregular joint, 70°, rough, rust stained - 30.31 planar joint, 60°, polished - 30.50 planar joint, 75°, rough 30.66 planar joint, 80°, rough	87	4				
31			- 31.17 planar joint, 75°, smooth	(37)	1				
			Bedding plane trace at 80° TCA						
32									
			- 32.41 planar joint, 75°, smooth	73 (43)	1				
33									

ABBREVIATIONS: JTS - JOINTS; W.L. & INSTR. - WATER LEVEL & INSTRUMENTATION; K - HYDRAULIC CONDUCTIVITY

Alberta ENVIRONMENT

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SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 6
SHEET 7 of 9

DEPTH ELEV (-)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	WL & INSTR	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
	SANDSTONE - medium grey - salt and pepper texture - medium to coarse grained - thickly bedded		- 33.11-33.50 possible core loss in this interval	73 (43)	0				
34	- fresh - very strong			87 (73)					
34.78			- 34.44-34.64 possible core loss in this interval		2				
1100.22 35	CLAYSTONE - dark greenish to blackish grey - medium bedded - fresh - weak - brecciated in zones		- 34.88 planar joint, 90°, smooth 35.00-35.15 brecciated - 35.15;35.21;35.27 3 undulating joints, 80° - 90°, slickensided 35.27-35.33 brecciated 35.33-35.69 possible core loss in this interval	77 (19)	9			D 17	
	greenish grey		- 35.90 planar joint, 5°, slickensided - 36.08 planar joint, 10°, slickensided 36.12;36.37 2 irregular joints, 60° - 65°, rough 36.30-38.00 15 joints, 80° - 90°.						
36	dark grey								
	greenish grey, silty		- 36.64;36.69 2 planar joints, 70° - 75°		11				
37				100 (67)					
	darker grey and siltier		- 37.37 undulating joint, 10°, smooth - 37.53;37.60;37.73 3 undulating joints, 60° - 65°, smooth		15				
38.00			- 37.94 undulating joint, 15°, rough						
1097	SILTSTONE - dark grey - thickly bedded - fresh			100 (81)	0				
39	- very strong		Bedding plane trace at 80° TCA						
			- 39.31;39.42 2 planar joints, 75°, smooth		4				
			39.82;39.84 2 irregular bedding joints, 80°, slickensided	93 (67)					
40									

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OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 6
SHEET 8 of 9

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	WL & INSTR.	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
	SILTSTONE - dark grey - thickly bedded - fresh - strong		-40.09-40.40 brecciated -40.22 planar joint, 35°, slickensided						
40.40			-40.36 planar joint, 75°, smooth	93	4			D 18	
1094.6	CLAYSTONE - blackish grey - thickly bedded - fresh - moderately strong		Bedding plane trace at 80° TCA	(67)					
41.08			-40.95 planar joint, 60°, smooth						
1093.9	SILTSTONE - dark grey - very thickly bedded - fresh - very strong			95	1				
42			-41.98 stepped joint, 75°, rough -42.14 planar joint, 40°, smooth	(93)					
42.73			-42.48 undulating joint, 75°, smooth		3				
1092.3	CLAYSTONE - blackish grey - silty - thickly bedded - fresh - strong		-43.00 planar joint, 20°, smooth 43.10;43.15 broken rock, slickensided 43.28 planar joint, 25°, polished	100 (68)					
43									
43.46									
1091.5	SILTSTONE - dark grey - thickly bedded - fresh - very strong		-43.78 planar joint, 55°, polished		3				
44			-44.28 planar joint, 65°, smooth						
44.85			Bedding plane trace at 80° TCA	100 (83)	1				
1090.2	CLAYSTONE - blackish grey - thickly bedded - fresh - weak		45.35-45.38 shear zone -45.50 undulating joint, 15°, polished 45.70-45.78 rock is broken up by drilling, fragments slickensided		4				
45									
45.85									
1089.2	SILTSTONE - dark grey - thickly bedded - fresh - very strong		-46.05 curved joint, 80°, smooth	98 (85)	2				
46									
47			-46.66 planar joint, 60°, smooth						

ABBREVIATIONS: JTS - JOINTS WL & INSTR - WATER LEVEL & INSTRUMENTATION

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OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 6
SHEET 9 of 9

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	W.L. & INSTR.	K (m/s)	TEST SAMPLE & TYPE	TEST RESULTS
	SILTSTONE - dark grey - very thickly bedded - fresh - very strong			94	4				
			47.70 planar joint, 60°, smooth	(71)					
			47.89;47.96 2 planar joints 85°, smooth 47.91 planar joint, 65°, smooth						
48									
	grading to CLAYSTONE				1				
48.76									
1086	2 CLAYSTONE - dark blackish grey - thickly bedded - fresh - moderately strong		48.80 planar joint, 45°, smooth 49.03 irregular joint, 5°, smooth 49.05 irregular joint, 90°, slickensided	100 (86)		Pz B			
49									
49.40									
1085	6 SILTSTONE - dark grey - thickly bedded - fresh - very strong		Bedding plane trace at 80° TCA		2				
50.00									
1085	END OF HOLE @ 50.0m								

ABBREVIATIONS:
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K - HYDRAULIC CONDUCTIVITY

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD

Subconsultant: KLOHN LEONOFF LTD

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 85 - 115

SHEET 1 of 10

CONTRACTOR(S) / DRILL RIG(S): A: Chilako Drilling - RE 1050 Auger; B: SDS Drilling - Mayhew 1000

RIG No. A DEPTH(m) 32.5 DATE Sep 5 & 11/85 HOLE DIAM 140mm TOP CASING A (El.) 1149.6m

RIG No. B DEPTH(m) 51.6 DATE Sep 30-Oct. 2/85 CORE DIAM 76mm TOP CASING B (El.) 1150.0m

LOCATION: SW 13-7-1-W5

COORDINATES: 5490561.9 N

-695.8 E

INITIAL DIP: VERTICAL

ELEVATIONS GROUND SURFACE: 1149.2m

ROCK SURFACE: 1108.2m

BOTTOM OF HOLE: 1097.6m

DEPTH ELEV (m)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE STATE	SAMPLE No.	PENETRATION TEST (Blows/0.15m)	UNCONFINED COMPRESSION kPa	PLASTIC LIMIT / WATER CONTENT / LIQUID LIMIT	UNIT WEIGHT (kN/m³)	COHESION (kPa)	ANGLE OF SHEARING RESISTANCE φ' (Deg)	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY (cm/sec)	PARTICLE SIZE (%) Clay / Silt / Sand / Gravel
0.00													
1149 0.20	TOPSOIL												
1149	CLAY(CH) - trace sand - trace gravel - silt seams and inclusions - gypsum crystals - high plasticity - hard - grey			E 1									
1													
2				B 2									
3				A 3									

SAMPLE

- UNDISTURBED
- DISTURBED
- NOT RECOVERED

- NATURAL WATER CONTENT (w)
- LIQUID LIMIT (w_L)
- PLASTIC LIMIT (w_P)
- UNCONFINED COMPRESSIVE STRENGTH MEASURED WITH POCKET PENETROMETER

SAMPLING METHOD

- A - SPLIT TUBE
- B - SHELBY TUBE
- C - PISTON SAMPLER
- D - CORE BARREL
- E - AUGER
- F - WASH

SUBCONSULTANT KLOHN LEONOFF LTD

LOGGED BY TKH/PP

APPD. BY: TKH

Alberta ENVIRONMENT

PRIME CONSULTANT
STANLEY ASSOCIATES ENGINEERING LTD

SUB-CONSULTANT
KLOHN LEONOFF LTD

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 85 - 115

SHEET 2 of 10

DEPTH ELEV (-)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE STATE	SAMPLE No	PENETRATION TEST (Blows/0.15m) • STANDARD PENETRATION	UNCONFINED COMPRESSION kPa	PLASTIC LIMIT / WATER CONTENT / LIQUID LIMIT	UNIT WEIGHT kN/m³	COHESION kPa	ANGLE OF SHEARING RESISTANCE ϕ Deg	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY k m/sec	PARTICLE SIZE (%)
	CLAY(CH) - trace sand - trace gravel - silt seams and inclusions - gypsum crystals - high plasticity - hard - grey			B 4									
5													
6	- slickensides			A 5									
7													
	- slickensides			B 6									
8													
9													
	- wavey structure			A 7									

SAMPLE

NO RECOVERY

DISTURBED

NATURAL WATER CONTENT

PLASTIC LIMIT

LIQUID LIMIT

Alberta ENVIRONMENT

PRIME CONSULTANT
STANLEY ASSOCIATES ENGINEERING LTD
SUBCONSULTANT
KLOHN LEONOFF LTD

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No BS - 115

SHEET 3 of 10

DEPTH ELEV (-)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE STATE	SAMPLE No	PENETRATION TEST (Blows/0.15m) ● STANDARD PENETRATION	UNCONFINED COMPRESSION (kPa)	PLASTIC LIMIT / WATER CONTENT / LIQUID LIMIT	UNIT WEIGHT (kN/m³)	COHESION (kPa)	ANGLE OF SHEARING RESISTANCE ● (Deg)	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY ● (cm/sec)	PARTICLE SIZE (%)
	CLAY(CH) - as above												
10.90 1138.3				B 3									
12	CLAY(CL-CI) (TILL) - silty - little to some sand - some gravel - coal specks - low to medium plasticity - hard - brown - massive			A 9									
13													
				A 10									
14													
15				A 11									

SAMPLE

SAMPLING METHOD

Alberta ENVIRONMENT

STANLEY ASSOCIATES ENGINEERING LTD

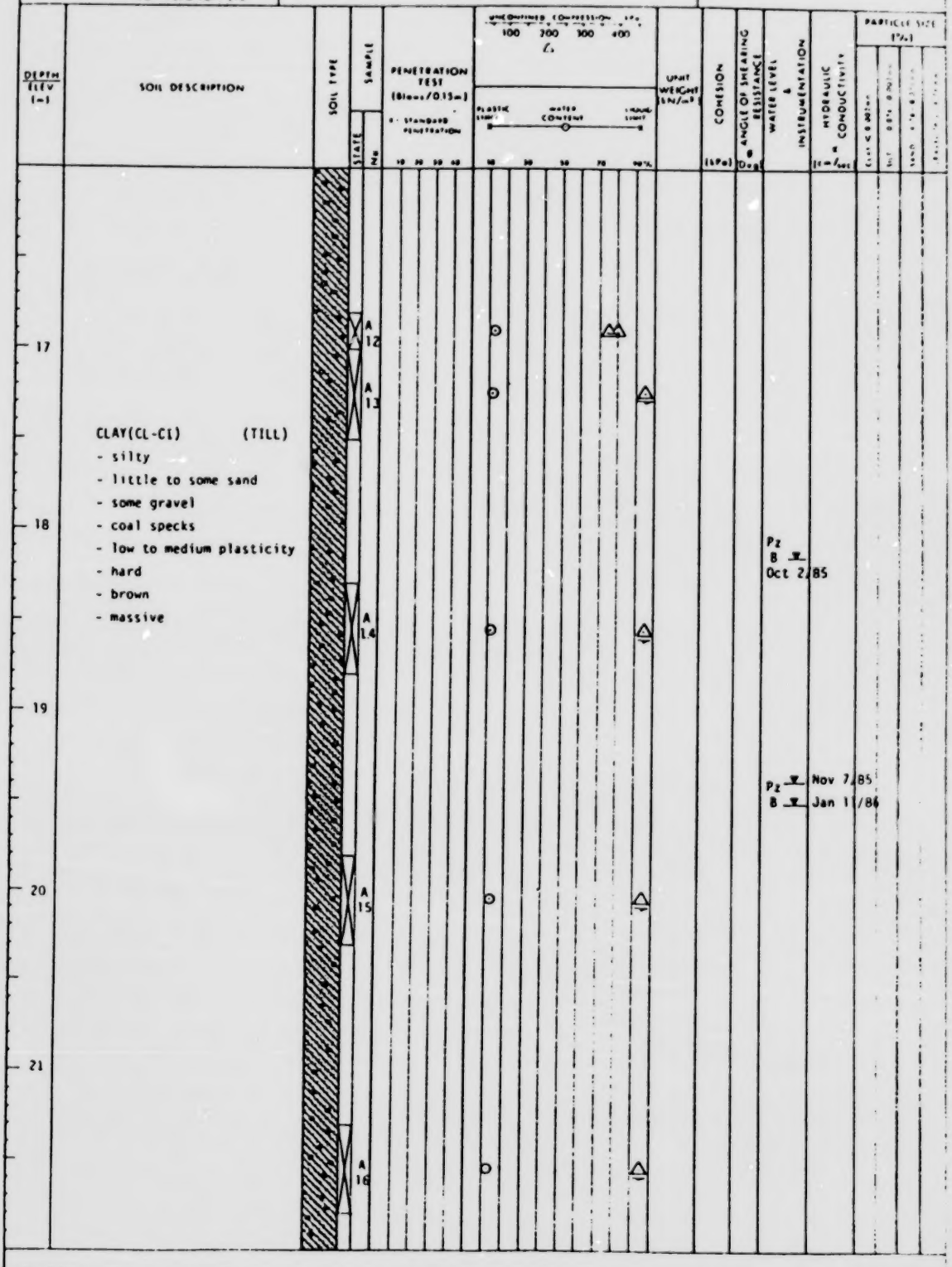
KLOHN LEONOFF LTD

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 85 - 115

SHEET 4 of 10



SAMPLE

Alberta ENVIRONMENT

prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD

subconsultant: KLOHN LEONOFF LTD

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 85 - 115

SHEET 5 of 10

DEPTH ELEV (-)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE STATE	SAMPLE No.	PENETRATION TEST (Blows/0.15m) ● - STANDARD PENETRATION	UNCONFINED COMPRESSION kPa	PLASTIC LIMIT / WATER CONTENT / LIQUID LIMIT %	UNIT WEIGHT kN/m³	COHESION kPa	ANGLE OF SHEARING RESISTANCE Deg	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY cm/sec	PARTICLE SIZE %
22.40	CLAY(CL-CI) (TILL) - as above												
1126.8													
	SILT(ML) - clayey - layers of low plastic silt and medium plastic clay - hard - brown			B 17									
23													
24				B 18									
24.60													
1124.6				A 19									
25	CLAY(CI) (TILL) - some sand - some gravel - medium plasticity - very stiff to hard - grey - massive												
26				A 20									
27													
				A 21									

SAMPLE

SAMPLING METHOD

Alberta ENVIRONMENT

PRIME CONSULTANT
STANLEY ASSOCIATES ENGINEERING LTD
SUBCONSULTANT
KLOHN LEONOFF LTD

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 85 - 115

SHEET 6 of 10

DEPTH ELEV (m)

SOIL DESCRIPTION

SOIL TYPE

SAMPLE
STATE
No

PENETRATION TEST (Blows/0.15m)
S - STANDARD PENETRATION
10 20 30 40

UNDRAINED COMPRESSION kPa
100 200 300 400
Cu

PLASTIC LIMIT — WATER CONTENT — LIQUID LIMIT
P — o — w
10 20 30 40 50%

UNIT WEIGHT (kN/m³)

COHESION (kPa)

ANGLE OF SHEARING RESISTANCE Φ Deg

WATER LEVEL & INSTRUMENTATION

HYDRAULIC CONDUCTIVITY K cm/sec

PARTICLE SIZE (%)
Clay & Colloids
Silt 0.002-0.06mm
Sand 0.06-2.0mm
Gravel 2.0-63mm

29
30
31
32
33
34

CLAY(CI) (TILL)
- some sand
- some gravel
- medium plasticity
- very stiff to hard
- grey
- massive

E 22
A 23
A 24
A 25

Slotted pipe A

Dry Sep 28/85
Dry Jan 10/86

Rig B - water loss between 33.0 and 34.5m. 4500 l. lost in this interval before circulation returned

SAMPLE
UNDISTURBED
DISTURBED
NOT RECOVERED

○ NATURAL WATER CONTENT (%)
— STANDARD PENETRATION (blows/0.15m)
P — PLASTIC LIMIT (%)
▲ UNDRAINED COMPRESSIVE STRENGTH (kPa)

SAMPLING METHOD
A - SPLIT TUBE
B - SHELBY TUBE
C - PISTON SAMPLER
D - CORE BARREL
E - AUGER
F - WASH

Alberta ENVIRONMENT

prime consultant: STANLEY ASSOCIATES ENGINEERING LTD

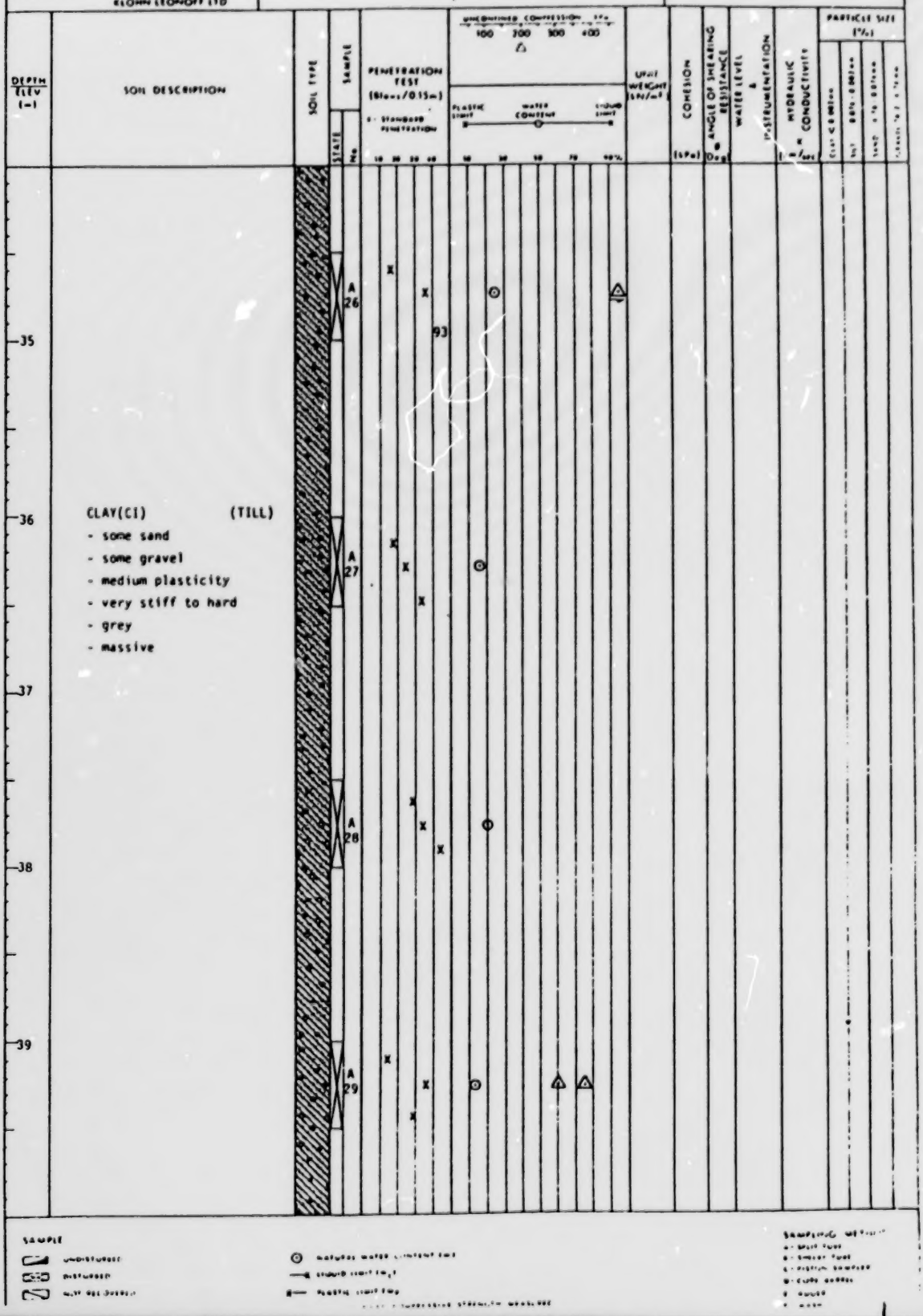
sub-consultant: KLOHN LEONOFF LTD

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 85 - 115

SHEET 7 of 10



Alberta ENVIRONMENT

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 85 - 115

SHEET 8 of 10

prime contractor: STANLEY ASSOCIATES ENGINEERING LTD

sub-contractor: KLOHN LEONOFF LTD

DEPTH ELEV (m)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE TYPE	SAMPLE No	PENETRATION TEST (Blows/0.15m)	UNCONFINED COMPRESSION (kPa)	UNIT WEIGHT (kN/m³)	COHESION (kPa)	ANGLE OF SHEARING RESISTANCE ϕ (Deg)	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY	PARTICLE SIZE (%)
	CLAY(CI) (TILL)											
	- as above		A	30								
41.00												
1108.2	CLAYSTONE											
42	- refer to sheet 9		A	31	100 For 50mm							
43												

SAMPLE

- undisturbed
- disturbed
- not recovered

- ⊙ natural water content (w)
- liquid limit (w_L)
- plastic limit (w_P)
- × unconfined compressive strength measured

SAMPLING METHOD

- A - split tube
- B - thin tube
- C - piston sampler
- D - core barrel
- E - auger
- F - other

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.
Subconsultant: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 115
SHEET 9 of 10

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC (ROD) (%)	JTS per m	WL & INSTR	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
	BEDROCK SILTSTONE; dark grey, clayey, fresh, moderately weak								
42 42.21									
1107	CLAYSTONE - dark blackish grey - thickly bedded - fresh - moderately strong		42.21-42.36 possible core loss 42.44 planar shear, 90°, slickensided 42.70 planar joint, 75°, smooth, tight 42.83-42.91 irregular shear 90°, rough, filled with clay gouge 43.16 planar shear, 85°, smooth, 1 cm of clay gouge	76 (0) 100 (80)	3				
43	becoming siltier and stronger		43.60-43.96 5 planar joints 70°-75°, rough, tight		7				
44.00									
1105.2	SILTSTONE - medium to dark grey - thickly bedded - fresh - strong to very strong - slightly calcareous		44.00 planar joint, 45°, smooth, tight 44.18;44.28 2 bedding fractures, 80°, with a clay infilling 44.77 bedding trace at 85°	100 (100) 98 (89)	4				
45	SANDSTONE; medium grey, fine grained medium grey, medium bedded, fresh, very strong		45.24 planar joint, 10°, smooth 45.31 planar joint, 30°, healed, rough		4				
45.85									
1103.3 46	SANDSTONE - light to medium grey - salt and pepper texture - medium to coarse grained - thickly bedded		46.37 planar shear, 70°, slickensided 46.70 irregular shear, 80°, rough, clay infilling	95 (67)	2				
47	- fresh - very strong - slightly calcareous		trace coal laminations and clay lumps	97 (66)	1				
48			47.78 joint, 75°, tight bedding 80° TCA						

ABBREVIATIONS:
JTS - JOINTS
CORE REC - CORE RECOVERY
WL & INSTR - WATER LEVEL & INSTRUMENTATION

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD
Subconsultant: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 115
SHEET 10 of 10

DEPTH TO TOP (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (TOTAL) (%)	JTS per m	WL & INSTR	α (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
				97					
			48.33-48.50 possible core loss	(66)	0				
			Drill breaks occur on bedding planes, predominantly 80°.						
49	SANDSTONE - light to medium grey - salt and pepper texture - fine to medium grained - thickly bedded - fresh - very strong - occassional thin beds of claystone			100					
				(79)	0				
50			Trace of clay lumps						
			Bedding 80° TCA	98	0				
				(61)					
51			51.00 stepped joint, 70°, rough, tight		2				
			51.54 planar joint, 75°, smooth, tight			Pz B			
51.60				100 (0)					
1097.6	END OF HOLE @ 51.6m								
52									

ABBREVIATIONS
JTS - JOINTS
WL & INSTR WATER LEVEL & INSTRUMENTATION

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.
Subconsultant: KLOHN LEONOFF LTD

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 85 - 119

SHEET 1 of 10

CONTRACTOR(S)/DRILL RIG(S): A: Chilako Drilling - RE 1050 Auger; B: SDS Drilling - Gardner Denver 1700

RIG No. A DEPTH(m) 16.8 DATE Sep 4/85 HOLE DIAM. 140mm TOP CASING A (El.) 1149.8m (approx)

RIG No. B DEPTH(m) 61.2 DATE Sep 16-17/85 CORE DIAM. 76mm TOP CASING B (El.) 1150.9m

LOCATION: NE 14-7-1-W5

COORDINATES: 5491384.7 N
-1633.0 E

INITIAL DIP: VERTICAL

ELEVATIONS: GROUND SURFACE: 1149.9m
ROCK SURFACE: 1129.9m
BOTTOM OF HOLE: 1088.7m

DEPTH ELEV (m)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE STATE	SAMPLE No.	PENETRATION TEST (Blows/0.15m) S - STANDARD PENETRATION	UNCONFINED COMPRESSION kPa (100 200 300 400) PLASTIC LIMIT / WATER CONTENT / LIQUID LIMIT (10 20 30 40 60%)	UNIT WEIGHT (kN/m³)	COHESION (kPa)	ANGLE OF SHEARING RESISTANCE (°)	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY (cm/sec)	PARTICLE SIZE (%)
0.00												
1149 0.20	9 TOPSOIL											
1149	7 CLAY(CH) - some silt - trace of sand - high plasticity - greyish brown to brown - very stiff to hard		A	1								
1			A	2								
2												
3	- slickensides visible in sample		B	3								

SAMPLE
- UNDISTURBED
- DISTURBED
- NOT RECOVERED

- NATURAL WATER CONTENT (%)
- LIQUID LIMIT (w_L)
- PLASTIC LIMIT (w_p)
- UNCONFINED COMPRESSIVE STRENGTH MEASURED WITH POCKET PENETROMETER

SAMPLING METHOD
- A - SPLIT TUBE
- B - SHELBY TUBE
- C - PISTON SAMPLER
- D - CORE BARREL
- E - AUGER
- F - WASH

SUBCONSULTANT : KLOHN LEONOFF LTD

LOGGED BY: TKM/IB

APPROVED TKM

Alberta ENVIRONMENT

prime consultant
STANLEY ASSOCIATES ENGINEERING LTD.

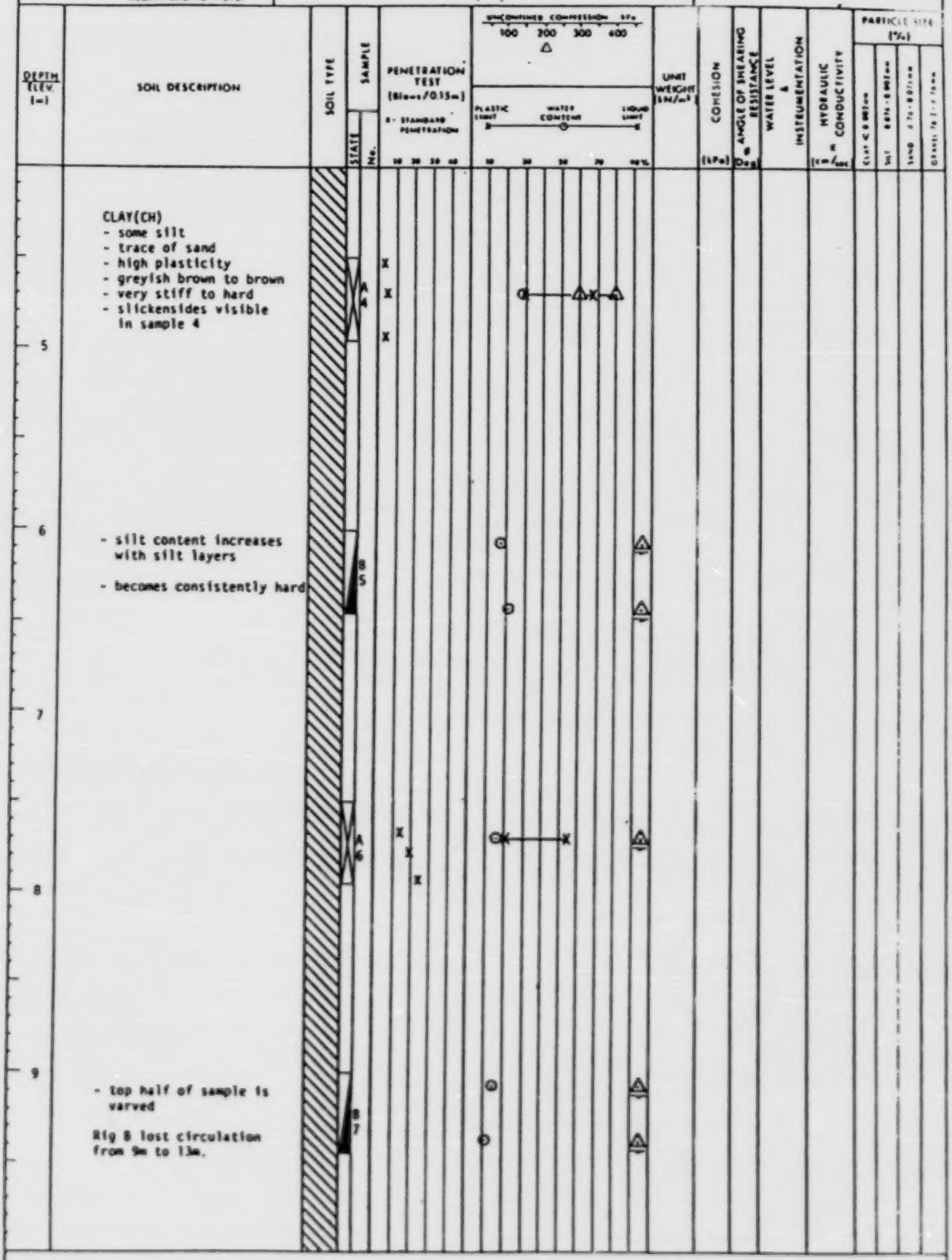
subconsultant
KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 119

SHEET 2 of 10



SAMPLE
- undisturbed
- disturbed
- not recovered

- natural water content (w)
- liquid limit (w_L)
- plastic limit (w_p)
- unconfined compressive strength measured

SAMPLING METHOD
A - Shelby tube
B - Denison tube
C - piston sampler
D - SPT split spoon
E - auger
F - core

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.

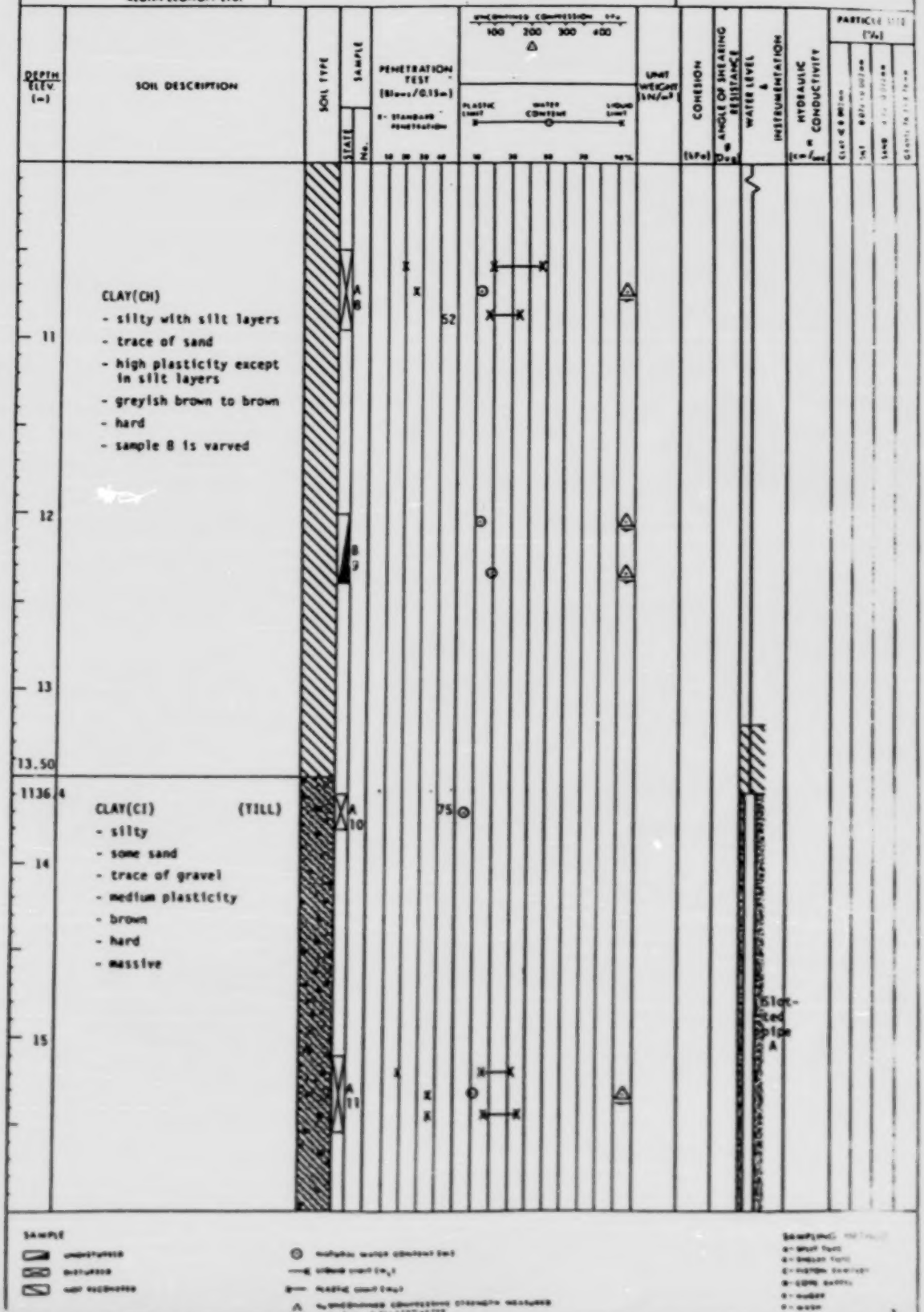
Subconsultant: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 119

SHEET 3 of 10



SAMPLE

- undisturbed
- disturbed
- not recovered

- natural water content test
- liquid limit (w_L)
- plastic limit (w_P)
- unconfined compressive strength measured

Alberta ENVIRONMENT

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 119

SHEET 4 of 10

Head Consultant: STANLEY ASSOCIATES ENGINEERING LTD

Sub-Consultant: KLOHN LEONOFF LTD.

DEPTH ELEV (m)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE STATE	SAMPLE No.	PENETRATION TEST (Blows/0.15m)	UNCONFINED COMPRESSION kPa	UNIT WEIGHT kN/m³	COHESION (kPa)	ANGLE OF SHEARING RESISTANCE Ø Deg.	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY K cm/sec	PARTICLE SIZE (%)
17	CLAY(CI) (TILL) - silty - some sand - trace of gravel - medium plasticity - brown - hard - massive			A 12	132	⊙				Dry Dec 1/85 Dry Jan11/86		
18												
19												
20.00				A 13								
1129.9	CLAYSTONE - refer to sheet 5											

SAMPLE
- undisturbed
- disturbed
- non recovery

⊙ natural water content (w)
liquid limit (w_L)
plastic limit (w_p)
Δ unconfined compressive strength measured

SAMPLING METHOD
A - split tube
B - shelby tube
C - piston sampler
D - core barrel
E - auger
F - wash

Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD.
SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 119
SHEET 5 of 10

DEPTH / ELEV (20.67)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC (R.Q.D.) (%)	JTS per m	WL & INSTR	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
1129	9 BEDROCK CLAYSTONE - olive to yellow brown - highly weathered		20.00-21.57 brecciated						
20.73	Begin coring at 20.73m								
1129	2 CLAYSTONE - olive - faintly laminated - slightly weathered - weak		21.32-21.36 breccia zone 21.41-21.50 4 planar joints 70°- 90°, smooth, pre-existing 21.57 breccia zone, 80°, 1 cm thick	90 (63)	>5				
21.74									
1128	2 SILTSTONE - olive - very thickly bedded - slightly weathered - moderately strong - slightly calcareous		22.20 stepped joint, 20°, rough 22.38;22.49 2 planar joints, 60°, smooth 22.73 curved joint, 90°, smooth, tight 22.86 planar joint, 20°, rough, tight 23.21 irregular joint, 60°, rough, tight	99 (81)	5				
24.14	CLAYSTONE; silty, mottled olive and greenish black clayey, mottled olive and greenish black, medium bedded, strong		23.46-23.70 sheared, small polished and slickensided surfaces 23.70-23.90 several bedding joints, 90°, oxidized 23.93 irregular joint, 90°, slickensided 24.09-24.36 3 undulating joints, 90°, smooth		10				
1125	8 SANDSTONE - mottled grey and white - fine grained - thickly bedded - fresh - strong - very slightly calcareous		24.60 planar joint, 10°, smooth, tight 25.14 undulating joint, 80°, rough 25.30-25.45 brecciated, and softened 25.62;25.80 2 joints, 90°, tight	98 (77)	9 4				
25.90									
1124	CLAYSTONE - silty - greenish grey - laminated - slightly weathered - weak blackish		26.07-26.42 6 bedding fractures, 90°, smooth 26.52-26.58 brecciated, soft clay infilling 26.64 breccia 26.85 breccia 26.96 planar shear, 40°, slickensided	92 (46)	14			M.C 4.8 L.L 27.9 P.L 20.4 P.I 7.5 Unit Wt 24.36 D 14	
27									

ABBREVIATIONS: JTS - JOINTS; WL & INSTR - WATER LEVEL & INSTRUMENTATION

Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD.
SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 119
SHEET 6 of 10

DEPTH ELEV (-)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	WL & INSTR	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
27.20	CLAYSTONE - blackish grey		- 27.10 irregular joint, 55° rough,						
1122.7	SILTSTONE - light bluish grey - thickly bedded - slightly weathered - extremely strong		- 27.56-27.57 breccia zone 27.64-28.22 7 planar joints 80°- 85°, rough, with rust staining - 27.85 planar shear, 80°, clay infill	92 (46)	10				
28	Drilling fluid loss occurs at 28.60m		- 28.41-28.82 4 planar joints 85°-90°, rust stained, smooth to rough	93 (67)	12				
	CLAYSTONE		- 28.75 planar joint, 30°, smooth, rust stained						
29			- 28.97 2 cm thick breccia zone - 29.08;29.13 2 curved joints 60°, smooth, rusty						
29.57			29.22;29.59;29.64 3 irregular joints, 90°, smooth, rust stained - 29.60 planar joint, 25°, smooth, rust stained		10				
1120.3	CLAYSTONE - bluish grey - medium bedded - slightly weathered - strong								
30			- 30.17-30.76 6 planar joints 90°, smooth, rust stained						
30.33									
1119.6	SANDSTONE - mottled light and dark grey - very fine to fine grained - thickly bedded - slightly weathered			89 (58)	9				
31			- 31.32 2 planar joints, 10°, 60°, smooth, rust stained						
31.40			31.40-31.42 breccia zone		12				
1118.5	CLAYSTONE - alternating light and dark grey - thinly bedded - fresh - moderately weak - carbonaceous partings								
32	blackish grey light grey blackish grey greenish to bluish grey			100 (94)	6			D 15	
33			- 33.10 planar joint, 90°, smooth, rust stained						
33.22									
1116.7	SILTSTONE - greenish grey - thinly bedded - fresh - moderately strong		- 33.25 planar joint, 30°, smooth, rust stained		4				
33.87			- 33.87;33.95 2 planar joints 90°, smooth						
1116	CLAYSTONE - greenish grey								

ABBREVIATIONS:
JTS - JOINTS
WL & INSTR - WATER LEVEL & INSTRUMENTATION

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.
Subconsultant: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 119
SHEET 7 of 10

DEPTH ELEV (-)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	WL & INSTR.	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
	CLAYSTONE - greenish grey - fresh - thickly bedded		- 34.17 planar joint, 60°, smooth, tight						
	SILTSTONE; light grey		- 34.36 planar joint, 29°, smooth, tight	100	5				
	dark grey, laminated, weak								
			- 34.80-34.84 breccia zone	(94)					
35			- 35.10-36.95 core is broken by drilling						
					8				
36									
					0				
37	dark grey, laminated, weak, fissile		- 37.07 breccia zone 2 cm thick						
				100	4				
				(99)					
38	lighter grey		Many drill induced fractures on bedding planes						
			Bedding 80°TCA						
					5			M.C	3.2
	SILTSTONE; light grey, fresh, very strong								non-plastic
								Unit Wt	25.18
39.06				100					
1110.8	SANDSTONE - light grey - thickly bedded - fresh - extremely strong - cross-bedded		- 39.05 planar joint, 80°, smooth, rust stained	(97)				D 16	
					1				
38.74									
1110.2	CLAYSTONE - dark grey to greenish blue - medium bedded - fresh - strong - carbonaceous partings								
40									
40.60					0				
1109.3	SILTSTONE - light purplish grey greenish grey, grades to fine grained SANDSTONE								
41									

ABBREVIATIONS:
JTS - JOINTS
WL & INSTR - WATER LEVEL & INSTRUMENTATION

Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD.

SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 119

SHEET 8 of 10

DEPTH ELEV (-)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS (per m)	WL & INSTR.	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
1108.9	SANDSTONE - greenish grey - fresh - fine grained - strong - medium bedded			100					
41.35			41.35 planar shear, 60°, polished, tight	(92)					
	CLAYSTONE - dark grey becoming greenish grey - laminated - fresh - weak - calcareous		41.35-41.45 sheared, high angle discontinuous slickensides, non-parallel 41.45 irregular shear, 30°, slickensided	100 (95)	2				
42								0 18	
			42.50 joint, curved 90°-0°, rough, rusty 42.57 planar joint, 90°, smooth, trace rust		2				
42.97									
1106.9	SILTSTONE - dark grey to greenish grey - thickly bedded - weak to strong - calcareous		43.20 planar joint, 80°, smooth, tight 43.30 planar joint, 30°, smooth, tight 43.42 irregular joint, 85°, rough, clay infill		4				
			43.80 breccia zone 2 cm thick	100					
44				(100)					
	greenish grey, laminated, fresh, extremely strong, calcareous, with calcareous nodules		44.54 undulating joint, 20° smooth, rust stained 44.67 irregular joint, 90°, rough, rust stained 44.74 irregular joint, 80°, rough, rust stained		4				
45									
			45.44 planar joint, 90°, smooth, rust stained		1				
46									
			46.44 irregular joint, 80°, rough, tight	100	3				
			46.77 planar joint, 30°, smooth, tight 46.82 stepped joint, 80°, rough, tight	(97)					
47	thin interbeds of SANDSTONE with cross-bedding								
			47.14 planar joint, 30°, smooth, tight		2				
				98					
48				(88)					

ABBREVIATIONS: JTS - JOINTS; WL & INSTR - WATER LEVEL & INSTRUMENTATION

Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD.
SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 119
SHEET 9 of 10

DEPTH ELEV (-)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	W.L. & INSTR.	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
48.10	SILTSTONE - greenish grey								
1101.8	CLAYSTONE - dark grey to black - thinly bedded - moderately strong - calcareous		48.20-48.23 curved shear, 90°, fresh 48.58 breccia zone 1 cm thick, gravel size particles and trace of clay	98 (88)	3			D 19	
49	trace of fossil shells		49.42 irregular joint, 80° rough, fresh	92 (92)	8				
50									
50.64			50.57 clay gouge, high plastic, possibly drill induced remolded claystone as clay gouge occurs at start of core run		3				
1099.3	SANDSTONE - bluish green - silty to very fine grained - medium bedded - fresh - strong								
51									
51.20			51.20-51.24 breccia zone some clay	100					
1098.7	CLAYSTONE - bluish green - medium bedded - fresh - strong - calcareous		51.41;51.54 2 irregular joints, 80°, rough, tight	(93)	4				
52	SILTSTONE; thickly bedded, fresh, strong to very strong, calcareous								
	dark greenish grey, thickly bedded, fresh, very strong, brown claystone lumps and calcite nodules		52.52-53.21 7 planar joints, 80°- 90°, tight	100 (88)	5				
53 53.15									
1096.8	SANDSTONE - dark greenish grey - laminated - fresh - extremely strong - trace calcite				6				
53.87			Bedding 80° TCA						
1096									
54	Interbedded CLAYSTONE and SILTSTONE - dark greenish grey - very thinly bedded - fresh - strong to extremely strong - contacts are gradational		54.00 planar joint, 85°, smooth, tight	100 (89)	6				
			54.65 planar joint, 50°, smooth, tight 54.90;54.99 2 curved joints 15°, rough, tight						
55									

ABBREVIATIONS:
JTS - JOINTS
CORE REC. - CORE RECOVERY
W.L. & INSTR - WATER LEVEL & INSTRUMENTATION

Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD.
SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 119
SHEET 10 of 10

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	W.L. & INSTR.	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
	Interbedded CLAYSTONE and SILTSTONE - dark greenish grey - very thinly bedded - fresh - strong		- 55.18 breccia zone, clay infill - 55.30-55.40 4 bedding joints, 90°, smooth, tight	100	10				
55.78			- 55.70-55.80 breccia zone						
1094.1 56 56.14	SANDSTONE - fine grained - extremely strong - light to dark grey - fresh - laminated - ripple marks			(90)				D 20	
1093.8	CLAYSTONE - dark to light grey - very thinly bedded - fresh - very strong - occassional silty layers - trace fossils on bedding planes		- 56.24-56.30 3 bedding joints, 85°, smooth, tight		5		1.9×10^{-4}		
57			- 56.90;57.15 2 planar joints, 20°, smooth, tight - 57.00 planar joint, 90°, smooth, tight			Pz B			
			- 57.30;57.33 2 planar joints, 40°, slickensides	100					
			- 57.57-57.60 breccia zone, random slickensides and clay gouge - 57.80 irregular shear, 60°, slickensides	(98)	9				
58	CLAY; mottled green and black, firm, gouge zone		- 58.10-58.46 clay gouge, clay; bluish-greenish grey mottled with black, firm						
	black, thickly bedded, fresh, strong				5			D 21	
59			- 58.90-58.97 shattered rock possibly drill induced						
59.20	silty		- 59.08-59.20 shattered rock with some clay gouge						
1090.7	SILTSTONE - light to dark grey - laminated - fresh - extremely strong				8				
59.94			- 59.84 bedding joint, 85°, smooth, tight						
1090	CLAYSTONE - dark grey to black - becoming bluish-greenish grey - thinly bedded - fresh - strong - silty interbeds		- 59.92 breccia shear zone, some clay gouge and discontinuous slickensides - 60.14 planar shear, 30°, slickensides, tight	83 (76)	3				
61									
61.21									
1088.7	END OF HOLE @ 61.21m								
62									

ABBREVIATIONS
JTS - JOINTS
WL & INSTR - WATER LEVEL & INSTRUMENTATION

B: 1986 TEST HOLE LOGS

TH 86-201

TH 86-202

TH 86-203

TH 86-204

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.
Subconsultant: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 86-201

SHEET 1 of 4

CONTRACTOR(S)/DRILL RIG(S): A: SDS Drilling - Becker Hammer B: SDS Drilling - Mayhew 1000

RIG No. A DEPTH(m) 3.0 DATE ____ HOLE DIAM. ____ TOP CASING A (El.) 1097.8 m

RIG No. B DEPTH(m) 18.1 DATE ____ CORE DIAM. 76 mm TOP CASING B (El.) -

LOCATION: ____

COORDINATES: 5491293.9 N
- 1368.7 E

INITIAL DIP: VERTICAL

ELEVATIONS: GROUND SURFACE: 1097.2 m
ROCK SURFACE: 1094.4 m
BOTTOM OF HOLE: 1079.1 m

DEPTH ELEV (m)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE STATE	SAMPLE No.	BECKER HAMMER PENETRATION (Blows/0.30m)	UNCONFINED COMPRESSION kPa (100 200 300 400)	PLASTIC / WATER CONTENT / LIQUID LIMIT (10 20 30 40 90%)	UNIT WEIGHT (kN/m³)	COHESION (kPa)	ANGLE OF SHEARING RESISTANCE (°)	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY (cm/sec)	PARTICLE SIZE (%) Clay < 0.002 mm	Silt 0.074 - 0.002 mm	Sand 4.76 - 0.074 mm	Gravel 76.2 - 4.76 mm
0.0																
1097.2	SAND - silty - some gravel - compact															
1																
2	GRAVEL - sandy - fine to coarse - cobbles - very dense				55 73 105 140											
2.74																
1094.4	SILTSTONE				100/0.28m											
3																

SAMPLE
- UNDISTURBED
- DISTURBED
- NOT RECOVERED

- NATURAL WATER CONTENT (w)
- LIQUID LIMIT (w_L)
- PLASTIC LIMIT (w_p)
- UNCONFINED COMPRESSIVE STRENGTH MEASURED WITH POCKET PENETROMETER

SAMPLING METHOD
- A - SPLIT TUBE
- B - SHELBY TUBE
- C - PISTON SAMPLER
- D - CORE BARREL
- E - AUGER
- F - WASH

SUBCONSULTANT : KLOHN LEONOFF LTD.

LOGGED BY: RM

APPROVED:

DATE: January, 1987

Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD.
SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 86-201
SHEET 2 of 4

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	WL & INSTR	K (m/s)	TEST SAMPLE & TYPE	TEST RESULTS
2.74	BEDROCK								
1094.4	SILTSTONE								
3.10	Begin coring at 3.1 m								
1094.1	SILTSTONE - dark grey - thinly bedded - moderately weathered - strong		- 3.10-3.30 core loss - 3.30-3.60 multiple joints in broken core - 3.60-3.71 core loss - 3.71-4.13 10 irregular joints, 60°-80°, rough	60 (0) 50 (0)	>20				
4 4.13									
1093.0	CLAYSTONE - dark greenish grey - thinly bedded - highly weathered - weak SILTSTONE; dark grey thinly bedded, moderately weathered, strong		- 4.55-4.83 9 irregular joints, 70°-80°, rough - 4.83-7.03 multiple slickensided joints	118 (0)	>10				
5				83	>10				
6					>10				
7			- 7.03-7.17 core loss - 7.17-7.57 core washed and remoulded	(89)	1				
7.80									
1089.4	SANDSTONE - medium grey - medium grained - medium bedded (cross bedded) - fresh - very strong SILTSTONE; dark grey, thinly bedded, freshly jointed, strong		- 7.97-8.07 2 irregular joints, 80°, rough	83	1				
8									
8.69			8.69-9.38 core loss						
1088.5	CLAYSTONE								
9									

ABBREVIATIONS:
JTS. - JOINTS
CORE REC. - CORE RECOVERY
RQD - ROCK QUALITY DESIGNATION
W.L. & INSTR. - WATER LEVEL & INSTRUMENTATION
K. - HYDRAULIC CONDUCTIVITY

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.
Subconsultant: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 86-201
SHEET 3 of 4

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	W.L. & INSTR	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
	CLAYSTONE cont'd - dark grey - thinly bedded - moderately weathered - weak		9.38-11.20 multiple slickensided joints	(100) 30 (0)	> 10				
	- dark greenish grey			87 (81)					
10	- completely weathered			111	> 10				
11									
11.20 1086.0	SILTSTONE - dark grey - thinly bedded - slightly weathered - strong		11.43-11.56 brecciated zone, (intersecting joints	(100)	> 5				
11.65 1085.5	SANDSTONE - medium grey - fine to medium grained - thickly bedded - fresh - extremely strong			100					
12	SILTSTONE: dark grey, thinly bedded, slightly weathered, strong		12.26-12.36 brecciated zone (intersecting joints)		2				
13			13.58 planar joint, 80°, rough	(88)	1				
14	14.40-14.80 salt & pepper texture			97	2				
	- fine grained		14.92 stepped joint, 80°, rough 14.92-15.03 & 14.95-15.06 2 subvertical joints, rough 15.15-15.30 2 irregular joints, 75°-80°, rough						
15			15.50-15.79 6 irregular joints, 70°-85°, rough 15.79-15.86 planar joint, 40°, rough 15.89 irregular joint, 80° rough	(95)	11				
16									

ABBREVIATIONS:
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Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.

Subconsultant: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 86-201

SHEET 4 of 4

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	W.L. & INSTR.	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
	SILTSTONE; dark grey, thinly bedded, slightly weathered, strong		16.00-16.15 planar joint, 25°, rough, tight 16.15-16.19 brecciated zone (intersecting joints)	100					
	SANDSTONE cont'd - medium grey - medium grained - thickly bedded - fresh - extremely strong		16.28 planar joint, 75°, rough 16.42-16.56 planar joint, 30°, rough		5				
17 17.18									
1080.0	CLAYSTONE - dark grey - medium bedded - moderately weathered (locally highly weathered) - weak		17.18 planar joint, 65°, smooth 17.18-17.89 multiple slickensided joints	(66)	>10				
18.05			core recovered to 17.89						
1079.1	END OF HOLE @ 18.05 m								
19									

ABBREVIATIONS:

JTS. - JOINTS
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W.L. & INSTR. - WATER LEVEL & INSTRUMENTATION
K. - HYDRAULIC CONDUCTIVITY

Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD.

SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 86-202

SHEET 1 of 4

CONTRACTOR(S)/DRILL RIG(S): A: SDS Drilling - Becker Hammer B: SDS Drilling - Mayhew 1000

RIG No. A DEPTH(m) 3.3 DATE _____ HOLE DIAM. _____ TOP CASING A (El.) 1097.8 m

RIG No. B DEPTH(m) 23.7 DATE _____ CORE DIAM. 76 mm TOP CASING B (El.) - _____

LOCATION: _____

COORDINATES: 5491274.6 N

- 1351.3 E

INITIAL DIP: VERTICAL

ELEVATIONS: GROUND SURFACE: 1097.2 m

ROCK SURFACE: 1094.2 m

BOTTOM OF HOLE: 1073.6 m

DEPTH ELEV (m)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE STATE	SAMPLE No.	BECKER HAMMER PENETRATION (Blows/0.30m)	UNCONFINED COMPRESSION kPa (100 200 300 400)	PLASTIC LIMIT / WATER CONTENT / LIQUID LIMIT (10 30 50 70 90%)	UNIT WEIGHT (kN/m³)	COHESION (kPa)	ANGLE OF SHEARING RESISTANCE (°)	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY (cm/sec)	PARTICLE SIZE (%) CLAY < 0.002 mm / SILT 0.002 - 0.07 mm / SAND 0.76 - 0.074 mm / GRAVEL 76.2 - 4.76 mm
0.0 1097.2	GRAVEL - sandy - fine to coarse - cobbles - very dense				62 52 54 53 59 76 73								
1 2 3.05 1094.2	CLAYSTONE				86/0.23 m								
4													

SAMPLE
- UNDISTURBED
- DISTURBED
- NOT RECOVERED

- NATURAL WATER CONTENT (w)
- LIQUID LIMIT (w_L)
- PLASTIC LIMIT (w_p)
- UNCONFINED COMPRESSIVE STRENGTH MEASURED WITH POCKET PENETROMETER

SAMPLING METHOD
- A - SPLIT TUBE
- B - SHELBY TUBE
- C - PISTON SAMPLER
- D - CORE BARREL
- E - AUGER
- F - WASH

SUBCONSULTANT : KLOHN LEONOFF LTD.

LOGGED BY: RH

APPROVED:

DATE: January 1987

Alberta ENVIRONMENT

STANLEY ASSOCIATES ENGINEERING LTD.

SUBCONSULTANT KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 86-202

SHEET 2 of 4

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	W.L. & INSTR.	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
3.05	BEDROCK								
1094.2	CLAYSTONE								
3.50	Begin coring at 3.5 m								
1093.7	CLAYSTONE - dark greenish grey - thinly bedded - completely weathered - very weak			98					
				(0)					
4				90					
				(0)	2				
				100					
5	SILTSTONE: dark grey, thinly bedded, slightly weathered, strong		– 4.94–5.30 9 irregular joints, 75°–80°, rough	(50)					
			– 5.30–5.53 brecciated zone	100	7				
6			– 6.00–6.93 multiple slickensided joints						
				(82)	>10				
7									
			– 7.50–7.98 rust staining	89	1				
7.98			– 7.98 planar joint 80°, rough						
1089.2	SANDSTONE - medium grey (salt & pepper texture) - fine to medium grained - medium bedded (cross-bedding) - freshly jointed - very strong		– 8.22 planar joint 80°, rough		>10				
8.86									
1088.4			– 8.87–9.21 multiple slickensided joints						
9	CLAYSTONE - black - thinly bedded - moderately weathered - weak		– 9.21–9.60 core loss	(100)					
					>10				
	- dark, greenish grey, locally highly weathered								
10			– 9.90–11.60 multiple						

ABBREVIATIONS:

JTS. - JOINTS
CORE REC. - CORE RECOVERY
R.Q.D. - ROCK QUALITY DESIGNATION

W.L. & INSTR. - WATER LEVEL & INSTRUMENTATION
K. - HYDRAULIC CONDUCTIVITY

Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD.
SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 86-202
SHEET 3 of 4

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	W.L. & INSTR.	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
	CLAYSTONE cont'd - dark greenish grey - thinly bedded - moderately weathered (locally highly weathered) - weak		slickensided joints	98	> 10				
11									
	- grading to SILTSTONE			(100)	> 10				
11.80									
1085.4	SILTSTONE - dark greenish grey - thinly bedded - slightly weathered - strong								
12.10			- 12.05-12.40 subvertical joint, rough						
1085.1	SANDSTONE - dark grey - fine grained - thinly bedded - freshly jointed - very strong		= 12.42 planar joint, 75°, smooth - 12.57 planar joint, 60°, rough - 12.76 planar joint, 40°, rough		4				
	SILTSTONE; dark grey, thinly bedded, freshly jointed, strong			97					
13	medium grey, medium grained, thickly bedded (cross bedding), fresh, extremely strong		- 13.00 curved joint, 30°, rough, tight						
			- 13.46 planar joint, 70°, rough		4				
			- 13.73-13.96 subvertical joint, rough						
14			- 13.81 planar joint, 80°, rough						
				(100)	0				
15			- 15.17 planar joint, 80°, rough						
			= 15.36-15.38 2 undulating joints, 80°, rough 15.43 planar joint, 80°, rough	116	7				
			= 15.43-15.67 subvertical joint, rough 15.70-16.02 subvertical joint, rough	(86)					
16			= 15.99 planar joint, 75°, rough = 16.23 planar joint, 85°, rough - 16.24-16.35 undulating joint, 30°, rough 16.47-16.62 curved joint, - 30° rough	81	3				
17			- 16.87-17.23 planar joint, 15°, rough						

ABBREVIATIONS:
JTS. - JOINTS
CORE REC. - CORE RECOVERY
RQD - ROCK QUALITY DESIGNATION
W.L. & INSTR. - WATER LEVEL & INSTRUMENTATION
K. - HYDRAULIC CONDUCTIVITY

Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD.
SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 86-202
SHEET 4 of 4

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	W.L. & INSTR.	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
	SANDSTONE cont'd - medium grey - medium grained - thickly bedded (cross bedding) - fresh - extremely strong				9				
17.47 1079.8	CLAYSTONE - dark grey - thinly bedded - moderately weathered - weak		17.47-17.76 8 irregular joints, 75°-80°, rough						
18			18.00-20.10 multiple slickensided joints	(88)	> 10				
	18.75-18.90 fossiliferous zone								
19			19.30 planar joint, 80°, smooth	123	> 10				
	dark greenish grey								
20 20.20	grading to SILTSTONE								
1077.0	SILTSTONE - dark greenish grey - thinly bedded - slightly weathered - strong		20.56-20.86 several joints in broken core	(100)	> 5				
	20.56-20.86 highly weathered, weak								
21									
21.36 1075.9	SANDSTONE - medium grey - medium grained - medium bedded (cross bedding) - freshly jointed - very strong		21.25-21.36 5 irregular joints, 75°-85°, rough		7				
	SILTSTONE: dark grey, thinly bedded, slightly weathered, strong		21.74-21.88 subvertical joint, rough 21.88-22.10 subvertical joint, rough	88					
22	SILTSTONE: dark grey, thinly bedded, slightly weathered, strong				2				
	SILTSTONE: dark grey, thinly bedded, slightly weathered, strong		22.58-22.76 subvertical joint, rough 22.75 irregular joint, 80°, rough						
23			23.00-23.25 subvertical joint, rough	(100)					
	SILTSTONE: dark grey, thinly bedded, slightly weathered, strong		core recovered to 23.40						
23.65 1073.6	END OF HOLE @ 23.65m								
24									

ABBREVIATIONS:
JTS. - JOINTS
CORE REC. - CORE RECOVERY
RQD - ROCK QUALITY DESIGNATION
W.L. & INSTR. - WATER LEVEL & INSTRUMENTATION
K. - HYDRAULIC CONDUCTIVITY

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.

Subconsultant: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 86-203

SHEET 1 of 6

CONTRACTOR(S)/DRILL RIG(S): A: SDS Drilling - Becker Hammer B: SDS Drilling - Mayhew 1000

RIG No. A DEPTH(m) 5.0 DATE _____ HOLE DIAM. _____ TOP CASING A (El.) 1098.0

RIG No. B DEPTH(m) 25.2 DATE _____ CORE DIAM. 76 mm TOP CASING B (El.) -

LOCATION: _____

COORDINATES: 5491240.8 N
- 1333.1 E

INITIAL DIP: VERTICAL

ELEVATIONS: GROUND SURFACE: 1097.4 m
ROCK SURFACE: 1092.5 m
BOTTOM OF HOLE: 1072.2 m

DEPTH ELEV (m)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE STATE	SAMPLE No.	BECKER HAMMER PENETRATION (Blows/0.30m)	UNCONFINED COMPRESSION kPa (100 200 300 400) / PLASTIC LIMIT / WATER CONTENT / LIQUID LIMIT (10 20 30 40 50%)	UNIT WEIGHT kN/m³	COHESION (kPa)	ANGLE OF SHEARING RESISTANCE Φ' (Deg)	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY K (cm/sec)	PARTICLE SIZE (%) CLAY < 0.002 mm / SILT 0.074 - 0.002 mm / SAND 4.76 - 0.074 mm / GRAVEL 76.2 - 4.76 mm
0.0 1097.4	GRAVEL - sandy - fine to coarse - cobbles - very dense				X	96						
1						84						
2						92						
						91						
						11						
3						90						
						80						
						70						
4						64						

SAMPLE
- UNDISTURBED
- DISTURBED
- NOT RECOVERED

- NATURAL WATER CONTENT (w)
- LIQUID LIMIT (w_L)
- PLASTIC LIMIT (w_p)
- UNCONFINED COMPRESSIVE STRENGTH MEASURED WITH POCKET PENETROMETER

SAMPLING METHOD
- A - SPLIT TUBE
- B - SHELBY TUBE
- C - PISTON SAMPLER
- D - CORE BARREL
- E - AUGER
- F - WASH

SUBCONSULTANT : KLOHN LEONOFF LTD.

LOGGED BY: RM

APPROVED:

DATE: January, 1987

Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD.

SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 86-203

SHEET 2 of 6

DEPTH ELEV. (m)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE STATE	SAMPLE No.	PENETRATION TEST (Blows/0.15m) S - STANDARD PENETRATION 10 20 30 40	UNCONFINED COMPRESSION kPa 100 200 300 400 △	PLASTIC LIMIT — WATER CONTENT — LIQUID LIMIT 10 30 50 70 90%	UNIT WEIGHT kN/m³	COHESION (kPa)	ANGLE OF SHEARING RESISTANCE ϕ Deg.	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY K (cm/sec)	PARTICLE SIZE (%) CLAY < 0.002mm	SILT 0.074 - 0.002mm	SAND 4.76 - 0.074mm	GRAVEL 76.2 - 4.76mm
	GRAVEL cont'd - sandy - fine to coarse - cobbles - very dense				65 66 104 42/100 mm											
4.88 1092.5	SILTSTONE															

SAMPLE
- UNDISTURBED
- DISTURBED
- NOT RECOVERED

- ⊙ NATURAL WATER CONTENT (w)
- —K— LIQUID LIMIT (w_L)
- ⊢— PLASTIC LIMIT (w_P)
- △ q_u UNCONFINED COMPRESSIVE STRENGTH MEASURED WITH POCKET PENETROMETER

SAMPLING METHOD
- A - SPLIT TUBE
- B - SHELBY TUBE
- C - PISTON SAMPLER
- D - CORE BARREL
- E - AUGER
- F - WASH

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.
Subconsultant: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 86-203
SHEET 3 of 6

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	W.L. & INSTR.	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
4.88	BEDROCK								
5.00	Begin coring at 5.0 m								
1092.4	SILTSTONE - dark greenish grey - thinly bedded - completely weathered - very weak		5.30-5.95 core loss	64 (0)					
				10 (0)					
6	- weak - grading to SANDSTONE			100 (64)					
6.55									
1090.9	SANDSTONE - medium grey (salt & pepper texture) - fine to medium grained - medium bedded - freshly jointed - very strong			80 (80)					
7.10			7.10-7.70 multiple slickensided joints 7.10-7.54 core loss	80 (100)					
1090.3	CLAYSTONE - black - thinly bedded - very weak to weak - moderately weathered - dark greenish grey, thickly bedded, locally highly weathered, weak			32 (0)	> 5				
8			8.14 planar joint, 50°, rough	68 (0)					
				112 (66)	1				
9	- moderately strong			121 (73)					
	- weak - dark grey - grading to SILTSTONE SILTSTONE; dark grey, very thinly bedded, slightly weathered, moderately strong			87	0				
10.12			10.12 planar joint, 75°, smooth						
1087.3	SANDSTONE - medium grey - fine grained - thickly bedded - fresh - very strong SILTSTONE; dark grey, very thinly bedded, moderately weathered, weak		10.44 stepped joint, 75°, rough	(83)	3				
11			10.88 planar joint, 55°, smooth						

ABBREVIATIONS:
JTS - JOINTS
CORE REC. - CORE RECOVERY
RQD - ROCK QUALITY DESIGNATION
W.L. & INSTR. - WATER LEVEL & INSTRUMENTATION
K. - HYDRAULIC CONDUCTIVITY

Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD.
SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 86-203
SHEET 4 of 6

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	WL & INSTR	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
	SANDSTONE cont'd - medium grey - fine grained - thickly bedded - fresh - very strong		11.10 irregular joint, 75°, rough 11.30 planar joint, 55°, rough	95	2				
12	- medium grained, cross bedded				0				
	- fine grained			(99)					
13									
			13.50 planar joint, 80° smooth	102	1				
14					2				
			14.65-14.69 2 irregular joints, 80°, smooth 14.85-15.48 subvertical joint, rough	(98)					
15									
15.48									
1081.9	gradational contact CLAYSTONE - dark grey - medium bedded - slightly weathered - moderately strong		15.48-15.52 2 planar joints, 75°, smooth 15.78 planar joint, 90°, smooth 15.80 slickensided joints		6				
16			16.18-16.51 5 planar joints, 80°, smooth	89					
	- highly weathered, weak		16.39-16.42 brecciated zone 16.51-16.70 brecciated zone 16.80-17.07 slickensided joints		7				
17									
				(90)	0				
	- grading to SILTSTONE								
18									

ABBREVIATIONS:
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Alberta ENVIRONMENT

PRIME CONTRACTOR: STANLEY ASSOCIATES ENGINEERING LTD.
SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 86-203
SHEET 5 of 6

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	W.L. & INSTR	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
18.10	CLAYSTONE cont'd		18.10 slickensided joints						
1079.3	SILTSTONE - dark greenish grey - medium bedded - moderately weathered (locally highly weathered) - strong to very strong (weak top 0.4 m)		18.42-18.46 2 planar joints 80°, smooth 18.80 irregular joint, 70°, smooth	107	5				
19			19.05 planar joint, 80°, smooth 19.65-19.72 brecciated zone (intersecting joints)	(77)	3				
20			20.25-20.26 brecciated zone		3				
21.00			20.70-20.75 2 irregular joints, 90°, smooth 20.93 planar joint, 80°, smooth	90					
1076.4	SANDSTONE - medium grey - fine grained - medium bedded - fresh - extremely strong		21.22-21.56 4 planar joints, 80°, smooth 21.40-21.50 brecciated zone (intersecting joints)	(88)	7				
22	SILTSTONE; dark greenish grey medium bedded, slightly weathered, strong		21.80-22.00 planar joint, 20°, rough	98					
	medium grained, cross bedded		22.41 stepped joint, 75°, rough 22.65-23.03 subvertical fracture, rough		2				
23	CLAYSTONE; dark grey, thinly bedded, slightly weathered, moderately strong		23.11 planar joint, 80°, smooth 23.62 planar joint, 80°, smooth 23.94 planar joint, 80°, smooth	(93)	3				
24 24.15			24.05 irregular joint, 80°, rough						
1073.3	SILTSTONE - dark grey - thinly bedded - slightly weathered- strong		24.15-24.17 & 24.20-24.23 brecciated zones 24.31 stepped joint, 80° smooth	98					
24.50 1072.9	CLAYSTONE - dark grey - very thinly bedded - moderately weathered - weak		24.44-24.45 brecciated zone core recovered to 24.60		2				
25									

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Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.

Subconsultant: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 86-203

SHEET 6 of 6

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	W.L. & INSTR	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
25.20	CLAYSTONE cont'd			(31)					
1072.2	END OF HOLE @ 25.20 m								
26									

ABBREVIATIONS:

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Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD.
SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 86-204

SHEET 1 of 6

CONTRACTOR(S)/DRILL RIG(S): A: Drilling - Becker Hammer. B: SDS Drilling - Mayhew 1000

RIG No. A DEPTH(m) 5.3 DATE ____ HOLE DIAM. ____ TOP CASING A (El.) 1098.4 m

RIG No. B DEPTH(m) 30.5 DATE ____ CORE DIAM 76 mm TOP CASING B (El.) ____

LOCATION: ____

COORDINATES: 5491217.1 N
- 1307.4 E

INITIAL DIP: VERTICAL

ELEVATIONS GROUND SURFACE: 1097.8 m
ROCK SURFACE: 1092.8 m
BOTTOM OF HOLE: 1067.3 m

DEPTH ELEV (m)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE STATE	SAMPLE No.	BECKER HAMMER PENETRATION (Blows/0.30m)	UNCONFINED COMPRESSION kPa (100 200 300 400) / PLASTIC LIMIT / WATER CONTENT / LIQUID LIMIT (10 20 30 70 90%)	UNIT WEIGHT (kN/m³)	COHESION (kPa)	ANGLE OF SHEARING RESISTANCE (°)	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY	PARTICLE SIZE (%)
0.0												
1097.8	SILT - sandy - a little gravel - compact											
1												
2												
2.13												
1095.7	SAND - silty - some gravel - compact											
3.05												
1094.8	GRAVEL - sandy - some cobbles - dense to very dense											
4												

SAMPLE
- UNDISTURBED
- DISTURBED
- NOT RECOVERED

- NATURAL WATER CONTENT (w_n)
- LIQUID LIMIT (w_L)
- PLASTIC LIMIT (w_p)
- UNCONFINED COMPRESSIVE STRENGTH MEASURED WITH POCKET PENETROMETER

SAMPLING METHOD
A - SPLIT TUBE
B - SHELBY TUBE
C - PISTON SAMPLER
D - CORE BARREL
E - AUGER
F - WASH

SUBCONSULTANT : KLOHN LEONOFF LTD.

LOGGED BY. RH

APPROVED:

DATE: January 1987

Alberta ENVIRONMENT

PRIME CONSULTANT
STANLEY ASSOCIATES ENGINEERING LTD.
SUBCONSULTANT
KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No 86-204

SHEET 2 of 6

DEPTH ELEV. (m)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE STATE	SAMPLE No.	BECKER HAMMER PENETRATION (Blows/0.30m)	UNCONFINED COMPRESSION kPa (100 200 300 400)	PLASTIC LIMIT / WATER CONTENT / LIQUID LIMIT (10 20 30 70 90%)	UNIT WEIGHT kN/m³	COHESION (kPa)	ANGLE OF SHEARING RESISTANCE ϕ (Deg)	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY K (cm/sec)	PARTICLE SIZE (%)
	GRAVEL cont'd - sandy - some cobbles - dense to very dense				X								
5.03 1042.8	SILTSTONE				75/0.15m								
6													

SAMPLE
- UNDISTURBED
- DISTURBED
- NOT RECOVERED

- ⊙ NATURAL WATER CONTENT (W)
- —X LIQUID LIMIT (W_L)
- X— PLASTIC LIMIT (W_P)
- △ q_u UNCONFINED COMPRESSIVE STRENGTH MEASURED WITH POCKET PENETROMETER

SAMPLING METHOD
- A - SPLIT TUBE
- B - SHELBY TUBE
- C - PISTON SAMPLER
- D - CORE BARREL
- E - AUGER
- F - WASH

Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD.
SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 86-204
SHEET 3 of 6

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	W.L. & INSTR.	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
5.03	BEDROCK								
1092.8	SILTSTONE								
5.74	Begin coring at 5.74 m		5.74-6.24 core reworked by drilling						
1092.1	SILTSTONE			0					
6	- dark grey - medium bedded - highly weathered - very weak			(0)					
				190	6				
	- dark greenish grey, thinly bedded, slightly weathered, strong		6.73 stepped joint, 80°, rough	(100)					
			6.84-7.12 8 irregular joints 90°, rough	86					
7			7.12-7.34 core loss	(0)					
	- dark grey		7.34-7.40 brecciated zone (intersecting joints)	80					
			7.49-7.74 6 irregular joints 90°, rough	(0)	11				
	- grading to CLAYSTONE								
	CLAYSTONE: dark grey with rust staining, thinly bedded, highly weathered, weak		7.89-8.02 brecciated zone with clay gouge	96					
8	- dark greenish grey		8.06 stepped joint, 80°, rough	(50)					
8.26			8.17-8.36 5 irregular joints, 80°, rough						
1089.6	SANDSTONE								
	- medium grey - fine to medium grained (salt & pepper texture) - medium bedded (cross bedding)			95	> 10				
8.76	- fresh jointed - very strong		8.76-9.40 multiple slickensided joints						
1089.1	CLAYSTONE								
9	- black - thinly bedded - moderately weathered - weak to very weak			(90)					
	dark greenish grey, thickly bedded, moderately weathered (locally highly weathered), weak				> 10				
10				101					
	- moderately strong				1				
11			10.77 planar joint, 80°, smooth						

ABBREVIATIONS:
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Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD.
SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 87-704
SHEET 4 of 6

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	W.L. & INSTR.	K (m/s)	TEST SAMPLE & TYPE	TEST RESULTS
11.15	CLAYSTONE cont'd		= 11.10-11.12 brecciated zone						
1086.7	SILTSTONE - dark greenish grey - thinly bedded - slightly weathered - strong			(100)					
	SANDSTONE: dark grey, fine grained, medium bedded, freshly jointed, very strong				2				
			- 11.85 stepped joint, 75°, rough						
12	- dark grey, fresh, very strong		- 11.95 curved joint, 75°, smooth - 12.04 planar joint, 80°, smooth	85					
	- moderately weathered, weak		- 12.16 stepped joint, 80°, rough						
	- grading to SANDSTONE		- 12.27-12.34 brecciated zone - 12.47 curved joint, 75°, smooth		6				
12.70									
1085.1	SANDSTONE - dark grey		- 12.57 stepped joint, 75°, rough 12.67 curved joint, 75°, rough						
13	- fine grained - thickly bedded - freshly jointed - very strong		12.82 planar joint, 80°, smooth		1				
			- 13.60-13.67 planar joint, 25°, rough, rust stained						
14			- 14.01 planar joint 75°, smooth	(90)					
			- 14.36-14.45 3 irregular joints, 75°, rough - 14.52-14.67 brecciated zone (intersecting joints, including one rust stained joint at ± 30°)	129	6				
15			- 15.17-15.55 subvertical joint, rough, rust stained						
			- 15.55 irregular joint, 80°, rough	(61)	6				
			- 15.65 stepped joint, 80°, rough - 15.77 planar joint, 50°, rough	-					
16			- 15.80-16.06 & 15.90-16.00 2 planar joints, 20°, rough rust stained						
16.14									
1081.7	CLAYSTONE - dark grey to dark greenish grey - medium bedded - slightly weathered - moderately strong - fossiliferous			99	0				
17			- 17.01-17.05 2 irregular joints, 80°, rough						
			= 17.29-17.31 brecciated zone	(100)	2				
17.57									
1080.3	SANDSTONE								
TB				63 (90)					

ABBREVIATIONS:
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Alberta ENVIRONMENT

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SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 86-204
SHEET 5 of 6

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	W.L. & INSTR	K (cm/s)	TEST: SAMPLE & TYPE	TEST: RESULTS
	SANDSTONE cont'd - medium grey - medium grained (salt & pepper texture) - thickly bedded (cross bedding) - fresh - extremely strong - oil bearing		18.06 irregular joint, 75° rough 18.62-18.72 2 intersecting irregular joints, 35° & 50°, rough	103	3				
19			19.72 oil seam		0				
20	CLAYSTONE: dark greenish grey, thinly bedded, moderately weathered, weak		19.98 oil seam 20.06-20.48 multiple slickensided joints 20.26 planar joint, 65°, smooth 20.54-20.62 curved joint, 40°, smooth 20.79 planar joint, 80°, rough	(100)	> 10				
21				107 (100)	3				
22			21.72-21.85 2 irregular joints, 65°, rough 21.82-22.02 & 21.89-22.13 2 planar joints, 20°, rough 22.30-22.54, planar joint, 20°, rough, tight 22.59 stepped joint, 80°, rough 22.71 irregular joint, 80°, rough 22.86 stepped joint, 80°, rough	97	6				
23	SILTSTONE: dark grey, thinly bedded, slightly weathered, strong		22.91 irregular joint, 80°, rough 23.22 planar joint, 50°, rough 23.74 planar joint, 80°, smooth 23.76-23.96 & 23.88-24.09 2 planar joints, 20°, rough		4				
24				(95)					
24.46 1073.4	SILTSTONE - dark grey - thinly bedded - slightly weathered - strong		24.46-25.00 12 irregular joints, 70°-80°, rough		12				
25									

ABBREVIATIONS:
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ROD - ROCK QUALITY DESIGNATION
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K. - HYDRAULIC CONDUCTIVITY

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.
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OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 86-204
SHEET 6 of 6

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	WL & INSTR.	K (m/s)	TEST SAMPLE & TYPE	TEST RESULTS
	SANDSTONE: medium grey, medium grained, medium bedded (cross bedded), fresh, extremely strong								
	SILTSTONE cont'd - dark grey - thinly bedded - slightly weathered - strong			94	>5				
25.77			- 25.77-27.19 multiple slickensided joints						
1072.1									
26	CLAYSTONE - dark grey - thinly bedded - moderately weathered - weak				>10				
	- dark greenish grey								
27				(82)					
27.19			- 27.20-28.20 18 irregular joints, 70°-80°, rough						
1070.6									
	SILTSTONE - dark greenish grey - thinly bedded - slightly weathered - strong				>20				
28									
			- 28.27-28.82 planar joint, 10°, rough	98					
					>10				
28.82			- 28.73-28.82 3 irregular joints, 80°, rough						
1069.0			28.82-29.38 multiple slickensided joints						
29	CLAYSTONE - dark grey - thinly bedded - moderately weathered - weak								
			- 29.38-29.77 subertical joint, rough		>10				
	SILTSTONE: dark greenish grey, thinly bedded, slightly weathered, strong								
	- dark greenish grey		- 29.77-30.03 multiple slickensided joints						
30			- core recovered to 30.03	(63)					
30.54									
1067.3	END OF HOLE @ 30.54 m								
31									

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Large Diameter Test Hole Log

Elevation	Depth	Lithology	Structural Details (S W N E S)	Description of Material	Knife Penetration (mm)
				Ground Elevation: 28.15 — Coordinates:	
1084.1	28.0			28.15	
				- joint at 28.90 - slickensided - rust stained SILTSTONE - dark grey - thinly bedded	1
				28.95	
1083.1	29.0			- joint at 29.40 - well developed - dipping at 60°S SANDSTONE - medium grey - fine grained - massive - medium grained below 29.50	0
1082.1	30.0			31.50	
				- slickensided - rust stained joints - orientations vary CLAYSTONE - medium grey grading to dark grey - laminated - moderately weathered	3
1081.	31.0			31.50 gradational contact	
				SILTSTONE - light greenish grey - thinly bedded - slightly weathered	2
				31.80	
1080.	32.0			- substructural fractures, east and west SANDSTONE - light greenish grey - massive - unweathered	
1079.1	33.0				
1078.1	34.0				
1077.1	35.0				

Notes

Alberta ENVIRONMENT

Project: OLDMAN RIVER DAM
RESERVOIR RELATED WORKS

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.

Subconsultant: KLOHN LEONOFF LTD.

Title

Approved	Date Of Issue	Revision Number	Dwg. No.

Large Diameter Test Hole Log

Elevation	Depth	Lithology	Structural Details (S W N E S)	Ground Elevation / Coordinates / Description of Material	Static Penetration (mm)
				SANDSTONE cont'd	
1077.1	35.0				
1077.1	35.0			END OF HOLE @ 35.36 m	
1076.1	36.0				

Notes

Alberta ENVIRONMENT

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Project: OLDMAN RIVER DAM
RESERVOIR RELATED WORKS

Title

Approved	Date of Issue	Revision Number	Dwg. no.

C: 1986 LDH LOGS

TH 86-West

TH 86-East

Large Diameter Test Hole Log

Ground Elevation 1110.0 m

Coordinates N 5491386.7 E -1387.8

Elevation	Depth	Lithology	Structural Details S W N E S	Description of Material	Knife Penetration (mm)
1110.0	0.0				
1109.0	1.0				
1103.0	7.0				
1102.0	8.0			- several joints - irregular - rough - clay filled - ±4 mm wide SANDSTONE - brownish grey - medium grained - salt & pepper texture - massive	0
1101.0	9.0			- SILTSTONE layer grading into CLAYSTONE 9.35	
1100.0	10.0			- scattered joints - shallow dipping - a few with slickensides - most with rust staining - failure along bedding planes common - rock crumbling into hole CLAYSTONE - greenish grey - laminated - highly weathered gradational change to dark grey or black	12
				- slightly weathered, gradational contact 10.70–10.80 10.80	5
1099.0	11.0			- few joints SILTSTONE - light greenish grey - massive with nodules of siderite - moderately weathered ← slightly weathered 11.80	1-3
1098.0	12.0			SILTSTONE	

Notes

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.

Subconsultant: KLOHN LEONOFF LTD.

Project: OLDMAN RIVER DAM
RESERVOIR RELATED WORKS

Title: LDH-West

Approval | Date Of Issue | Revision Number | Dwg No

Large Diameter Test Hole Log

Ground Elevation | Coordinates

Elevation	Depth	Lithology	Structural Details (S W N E S)	Description of Material	Knife Penetration (mm)
1098.0	12.0			- scattered joints - steeply dipping - rough - some filled with calcite **SANDSTONE** - medium grey - fine grained - massive	0
				12.30	
				- scattered joints - steeply dipping - rough - minor slickensides on bedding **SILTSTONE** - light greenish to dark grey - thinly bedded - slightly weathered	3
1097.0	13.0				
				- moderate number of well developed joints - steeply dipping - curved - rough - up to 2 mm wide - medium grey, massive	1
1096.0	14.0			14.00 gradational contact	
				- moderate number of joints - steeply dipping - curved - rough - some rust stained - up to 2 mm wide - some thrusting on joints - a few blocks caved into hole **SANDSTONE** - medium grey - medium grained - salt and pepper texture - massive	0
1095.0	15.0			15.10	
				- scattered joints - steeply dipping - smooth - a few blocks caved into into hole **SILTSTONE** - medium grey - thinly bedded - slightly weathered - top 20 mm is weathered and rust stained	3
				15.90	
1094.0	16.0			- a few joints - rough - steeply dipping **CLAYSTONE** - dark grey - moderately weathered - SILTSTONE: medium grey thinly bedded, slightly weathered, gradational contact	5
				← greenish grey	
				16.70 - a few joints, rough, steeply dipping	1
1093.0	17.0			- a few joints - rough - steeply dipping **SANDSTONE** - medium grey, fine grained - massive	0
				17.00 gradational contact	
				- moderate number of joints - rough - steeply dipping - several blocks caved into hole **SILTSTONE** - medium grey - medium bedded - massive with small calcite nodules	1
1092.0	18.0			18.20	
				CLAYSTONE - dark grey - laminated - moderately weathered	8
				18.50	
				- scattered joints - rough - steeply dipping - tight to 1 mm wide **SILTSTONE** - medium grey - thinly bedded	1
1091.0	19.0			19.50 gradational contact	

Notes

Alberta ENVIRONMENT

Project: **OLDMAN RIVER DAM**
RESERVOIR RELATED WORKS

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.

Subconsultant: KLOHN LEONOFF LTD.

Title: LDH-West

Approved | Date Of Issue | Revision Number | Dwg No

Large Diameter Test Hole Log

Ground Elevation:

Coordinates:

Elevation	Depth	Lithology	Structural Details (S W N E S)	Description of Material	Knife Penetration (mm)
1091.0	19.0			SILTSTONE cont'd	
				19.50 gradational contact	
1090.0	20.0			- several joints - rough - steeply dipping - tight to 2 mm wide - iron stained - water bearing to 20.00 SANDSTONE - medium grey - fine grained - massive	0
				20.40	
1089.0	21.0			- scattered joints - smooth - steeply dipping - some bedding planes separated and open SILTSTONE - medium grey - thinly bedded	1
				21.40	
				CLAYSTONE - dark grey - slightly weathered	5
				21.90	
1088.0	22.0			- scattered joints - smooth - steeply dipping - some failures along joints and bedding SILTSTONE - light greenish grey - massive - slightly weathered	1-3
				22.50 thinly bedded, moderately weathered	
1087.0	23.0			- scattered joints - rough - steeply dipping - tight SANDSTONE - medium grey - fine grained - massive	0
				23.10	
1086.0	24.0			- scattered joints - tight - breaking along bedding planes SILTSTONE - light grey - thinly bedded	
				- scattered joints, steeply dipping, rough, tight - several joints, well developed, dipping at ±45°, some slickensides on bedding	
				- 24.10-24.60 weak and crumbling	2
1085.0	25.0			- scattered joints, dipping at ±45°	
1084.0	26.0				

Notes

Alberta ENVIRONMENT

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Project: OLDMAN RIVER DAM
RESERVOIR RELATED WORKS

Title: LDH-West

Approved	Date of Issue	Revision Number	Dwg No

Large Diameter Test Hole Log

Ground Elevation

Coordinates

Elevation	Depth	Lithology	Structural Details (S W N E S)	Description of Material	Knife Penetration (mm)
1084.0	26.0			26.10	
				- scattered joints - steeply dipping - rough - failure along bedding and joints CLAYSTONE - dark grey - laminated - slightly weathered	3
				26.40	
1083.0	27.0			- scattered joints - steeply dipping - rough - failure along bedding and joints SILTSTONE - medium grey - thinly bedded	2
				27.50	
				- scattered joints - dipping at 45° - some failure along bedding and joints CLAYSTONE - silty - dark grey - laminated - slightly weathered	5
				27.70	
1082.0	28.0			- scattered joints - dipping vertical to 60° - smooth - tight to 1/2 mm wide SANDSTONE - dark grey - massive - unweathered	0
				28.85	
1081.0	29.0			- frequent joints - shallow to steeply dipping - smooth to rough - some with slickensides CLAYSTONE - light greenish grey - laminated - slightly weathered - weak	5
1080.0	30.0			30.60	
1079.0	31.0			SILTSTONE - medium grey - massive - slightly weathered	1
				31.80	
1078.0	32.0			SANDSTONE - dark grey - massive - unweathered	0
1077.0	33.0				

Notes

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.

Subconsultant: KLOHN LEONOFF LTD.

Project: OLDMAN RIVER DAM
RESERVOIR RELATED WORKS

Title

Approved | Date of Issue | Revision Number | Dwg. No.

Large Diameter Test Hole Log

Elevation	Depth	Lithology	Structural Details (S W N E S)	Description of Material	Knife Penetration (mm)
				Ground Elevation:	Coordinates:
1077.0	33.0			SANDSTONE -dark grey -massive -unweathered	
1076.0	34.0				
1075.0	35.0				
1074.0	36.0				
				END OF HOLE @ 36.27 m	

Notes

Alberta ENVIRONMENT

Project: OLDMAN RIVER DAM
RESERVOIR RELATED WORKS

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.

Subconsultant: KLOHN LEONOFF LTD

Title

Approved | Date Of Issue | Revision Number | Dwg No

Large Diameter Test Hole Log

Ground Elevation 1112.1 m

Coordinates N 5491229.2
E -1247.2

Elevation	Depth	Lithology	Structural Details (S W N E S)	Description of Material	Field Description
1111	1.0				
				Cased off to 2.00 m	
1110	2.0			2.00	
				- numerous weak seams filled with brown silt - a few joints - well developed - dipping ± 70°S - rough - tight to 1 mm wide - rust stained SILTSTONE - medium grey - laminated - weathered	
				2.30	
1109	3.0			- a few joints - well developed - dipping vertical to 70°S and 45°SW - irregular - rough - tight - rust stained SANDSTONE - medium grey - medium grained - massive - silty - weathered 2.30-3.40	
1108	4.0			4.40	
				A few rust stained joints, rough and irregular, (similar to sandstone above). SILTSTONE - light to medium grey - unweathered - occasional sandy zones	
1107	5.0				
1106	6.0			6.00	
				- major open joints from 6.90 to 9.85 - some joints partly filled with brown clay - rust stained - 20 to 30 mm wide - dipping approximately 60°S - one irregular joint, approximately vertical, trending south SANDSTONE - brownish grey - medium to coarse grained - salt and pepper texture - minor zones of flat clasts and pebbles of siltstone and coal - massive - some cross bedding	
1105	7.0				

Notes

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.

Subconsultant: KLOHN LEONOFF LTD

Project: OLDMAN RIVER DAM
RESERVOIR RELATED WORKS

Title: LDH-East

Approved | Date Of Issue | Revision Number | Dwg No. 1 of 6

Large Diameter Test Hole Log

Ground Elevation

Coordinates N 5491229.2
E -1247.2

Elevation	Depth	Lithology	Structural Details S W N E S	Description of Material	Knife Penetration (mm)
1105.1	7.0				
1104.1	8.0				
1103.1	9.0				0
1102.1	10.0				
1101.1	11.0			11.05 - abrupt contact at 11.05m - rust staining on joints SILTSTONE - medium grey - laminated - freshly jointed - weak	1
				11.50 - frequent joints - some slickensided - vertical to shallow dipping green with dark grey streaks, massive CLAYSTONE - dark grey - laminated - slightly weathered - gradational contact to green CLAYSTONE	2-6
1100.1	12.0			12.80	
1099.1	13.0			- slickensided joints - orientations vary SILTSTONE - brownish grey - thinly bedded - slightly weathered	2
1098.1	14.0				

Notes

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.

Subconsultant: KLOHN LEONOFF LTD.

Project: OLDMAN RIVER DAM
RESERVOIR RELATED WORKS

Title: LDH-East

Approved | Date Of Issue | Revision Number | Dwg No

Large Diameter Test Hole Log

Ground Elevation:

Coordinates:

Elevation	Depth	Lithology	Structural Details (S W N E S)	Description of Material	Knife Penetration (mm)
1098.1	14.0			SILTSTONE cont'd - gradiational contract to greenish grey SILTSTONE	
				- greenish grey, massive, unweathered, locally sandy	1
1097.1	15.0			15.01	
				- few joints - steeply dipping - tight	0
				15.50 SANDSTONE - medium grey - fine grained - massive with siderite nodules	
1096.1	16.0			- smooth joints - dip varies from vertical to 45° at various orientations	1
				SILTSTONE - medium grey - massive - upper part of layer is sandy - freshly jointed	
				16.80	
1095.1	17.0			- slickensided surfaces at 17.00	4
				CLAYSTONE - light greenish grey (dark grey from 17.10 to 17.35) - laminated - moderately weathered	
				17.70	
1094.1	18.0			- a few well developed joints - most dipping steeply south at approximately 65° - tight - rough	1
				SILTSTONE - medium grey with some darker grey bands - massive - freshly jointed	
1093.1	19.0			- 19.60-19.80 laminated	4
1092.1	20.0			- gradational contact 20.45 to 20.55	1
				20.55	
				- a few joints dipping at 70°S - a few vertical joints trending east and south	0
				SANDSTONE - medium grey - fine to medium grained - massive - water bearing	
1091.1	21.0				

Notes

Alberta ENVIRONMENT

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.

Subconsultant: KLOHN LEONOFF LTD.

Project: OLDMAN RIVER DAM
RESERVOIR RELATED WORKS

Title:

Approved | Date Of Issue | Revision Number | Dwg No

Large Diameter Test Hole Log

Ground Elevation:

Coordinates:

Elevation	Depth	Lithology	Structural Details (S W N E S)	Description of Material	Knife Penetration (mm)
1091.1	21.0			SANDSTONE cont'd	
				21.40	
				SILTSTONE - medium grey - laminated - slightly weathered	2
1090.1	22.0			22.05	
				- little jointing — abrupt change to dark grey	2
				CLAYSTONE - silty - medium grey - laminated - slightly weathered	4
				22.60	
				- little jointing	1
				22.90	
1089.1	23.0			SILTSTONE - greenish grey - massive gradational contact - unweathered	
				- joints dipping at ±60°S - ore exposed at 23.00 on north side	0
1088.1	24.0			SANDSTONE - light grey - medium grained - massive	
				gradational contact 24.00 to 24.20	
				24.20	
				- a few vertical joints - poorly developed	
				SILTSTONE - dark greenish grey - slightly weathered - massive	2
1087.1	25.0			- 26.1-26.4 SANDSTONE; medium grey, fine grained	
				vertical joint at 26.00, slickensided	
1086.1	26.0			26.1-26.4 SANDSTONE; medium grey, fine grained	0
				- joint at 27.00-27.55 - well developed - steeply dipping to west - less well developed - less steeply dipping to south	2
1085.1	27.0			27.70 gradational contact	
				- dipping ± 70°-80°S	
				SANDSTONE - light to medium grey	0
1084.1	28.0				

Notes

Alberta ENVIRONMENT

Project: OLDMAN RIVER DAM
RESERVOIR RELATED WORKS

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.

Subconsultant: KLOHN LEONOFF LTD.

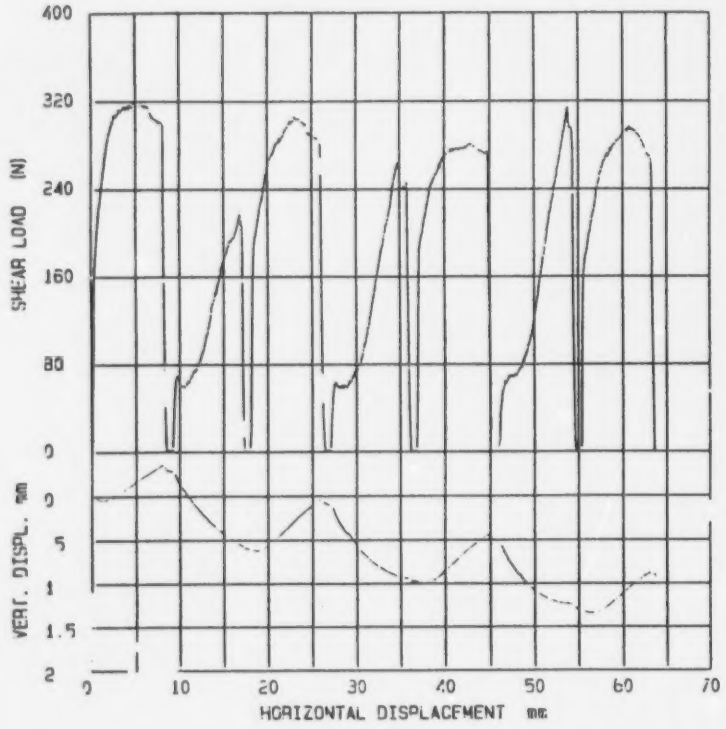
Title

Approved | Date Of Issue | Revision Number | Dwg No

APPENDIX II

Residual Direct Shear Test Results

RESIDUAL DIRECT SHEAR TEST RESULTS



OLD MAN RIVER PA206202
WEST 1081 Sa 1X
NORMAL LOAD 720 Newtons
NORMAL PRESSURE 200 kPa
60mm sq Shear Box
DISPLACEMENT RATE .012 mm/min

Alberta ENVIRONMENT

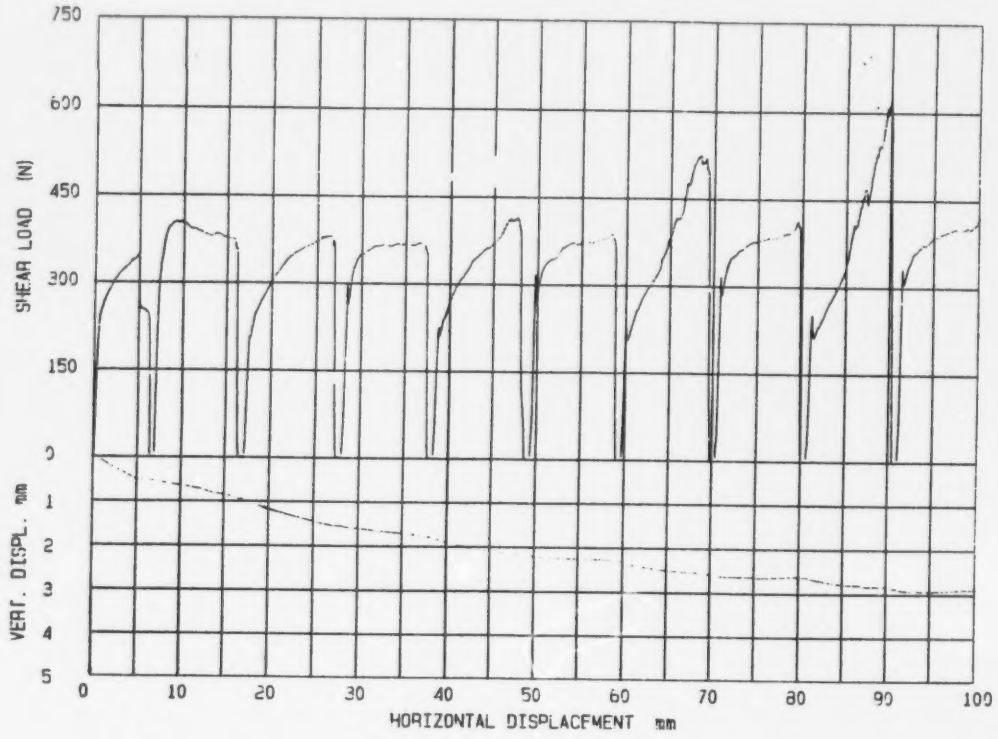
Project: OLDMAN RIVER DAM
RESERVOIR RELATED WORKS

Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.
Subconsultant: KLOHN LEONOFF LTD.

Title: RESIDUAL DIRECT SHEAR TEST RESULTS

Approved	Date Of Issue	Revision Number	Dwg. No.

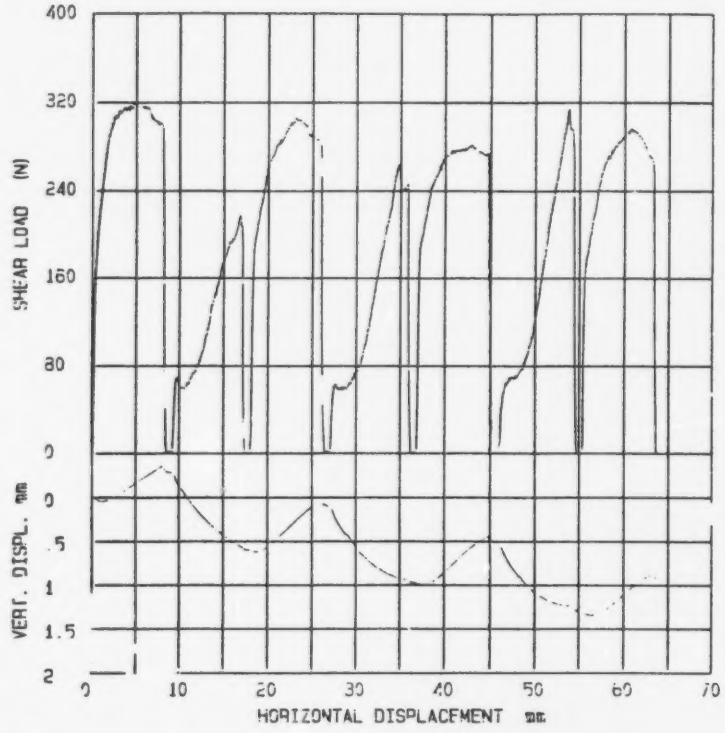
RESIDUAL DIRECT SHEAR TEST RESULTS



OLD MAN RIVER P4206202
WEST 1081 Sa 1K
NORMAL LOAD 1440 Newtons
NORMAL PRESSURE 400 kPa
60mm sq Shear Box
DISPLACEMENT RATE .012 mm/min

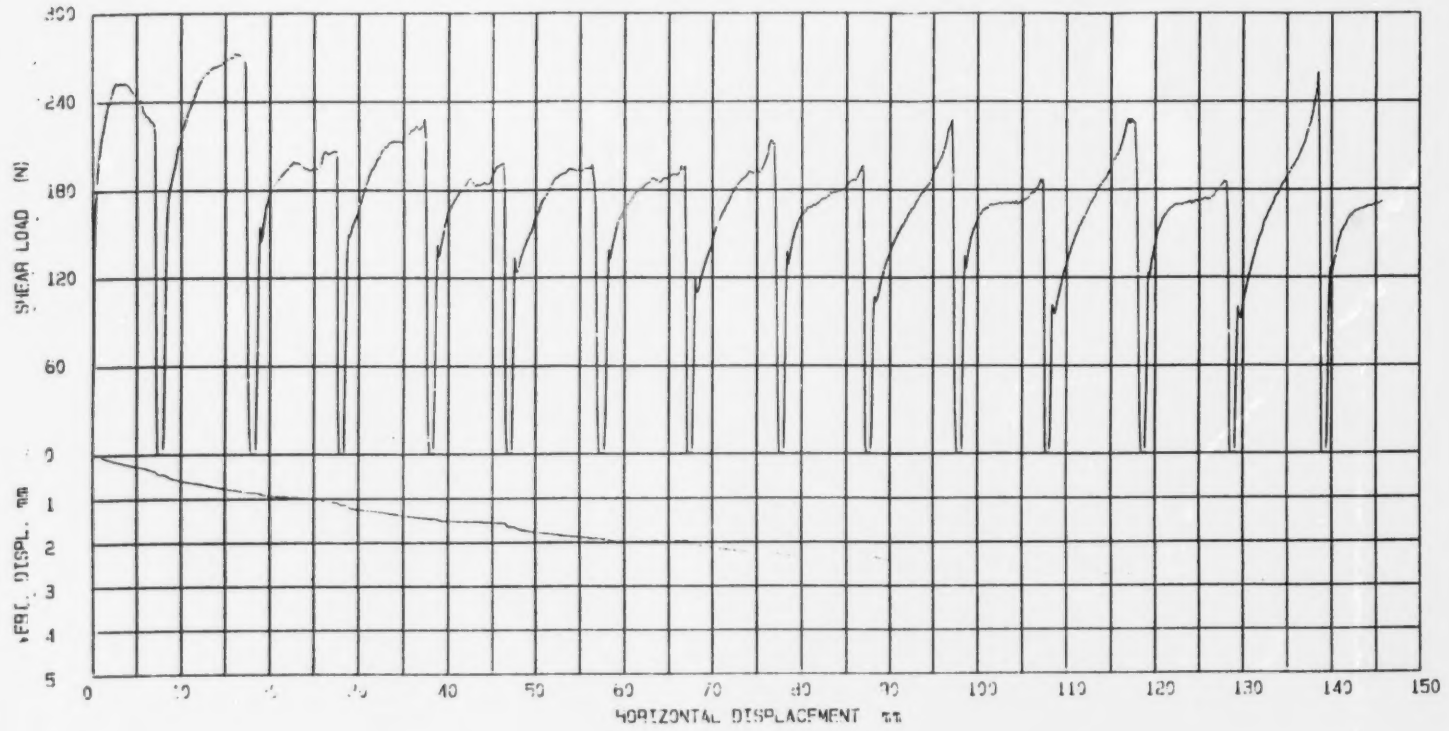
Alberta ENVIRONMENT	Project	OLDMAN RIVER DAM RESERVOIR RELATED WORKS
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD. Subconsultant: KLOHN LEONOFF LTD.	Title	RESIDUAL DIRECT SHEAR TEST RESULTS
	Approved / Date Of Issue / Revision Number / Dwg. No.	

RESIDUAL DIRECT SHEAR TEST RESULTS



OLD MAN RIVER PA206202
WEST 1081 Sa 1X
NORMAL LOAD 720 Newtons
NORMAL PRESSURE 200 kPa
60mm sq Shear Box
DISPLACEMENT RATE .012 mm/min

Alberta ENVIRONMENT	Project: OLDMAN RIVER DAM RESERVOIR RELATED WORKS			
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title: RESIDUAL DIRECT SHEAR TEST RESULTS			
Subconsultant: KLOHN LEONOFF LTD.	Approved	Date Of Issue	Revision Number	Dwg. No.

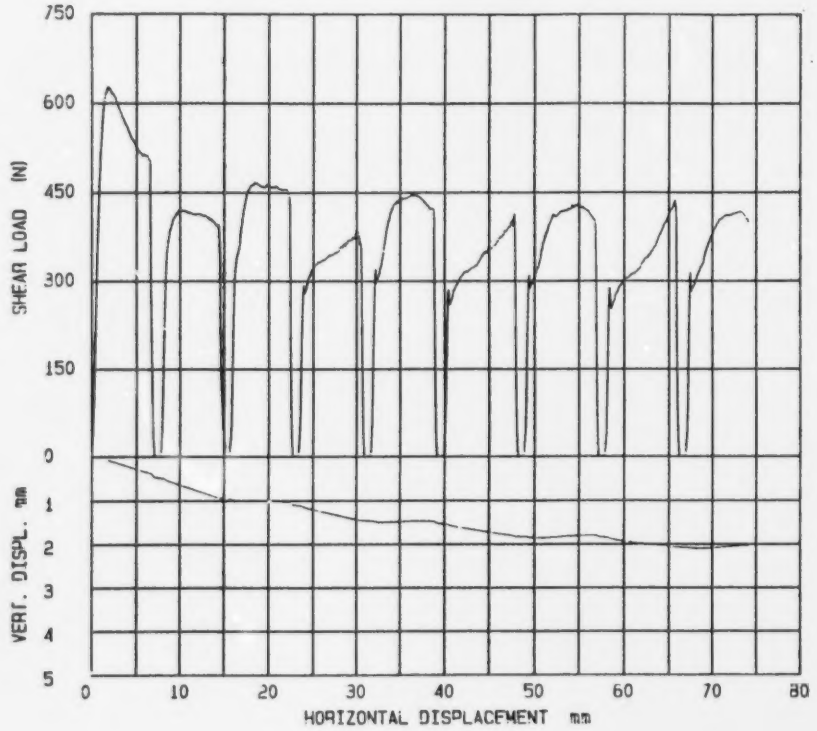


RESIDUAL DIRECT SHEAR TEST RESULTS

OLD MAN RIVER PA206202
WEST 1081 Sa 1C
NORMAL LOAD 720 Newtons
NORMAL PRESSURE 200 kPa
60mm sq Shear Box
DISPLACEMENT RATE .012 mm/min

Alberta ENVIRONMENT	Project: OLDMAN RIVER DAM RESERVOIR RELATED WORKS		
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title: RESIDUAL DIRECT SHEAR TEST RESULTS		
Subconsultant: KLOHN LEONOFF LTD.	Approved	Date Of Issue	Revision Number / Dwg. No.

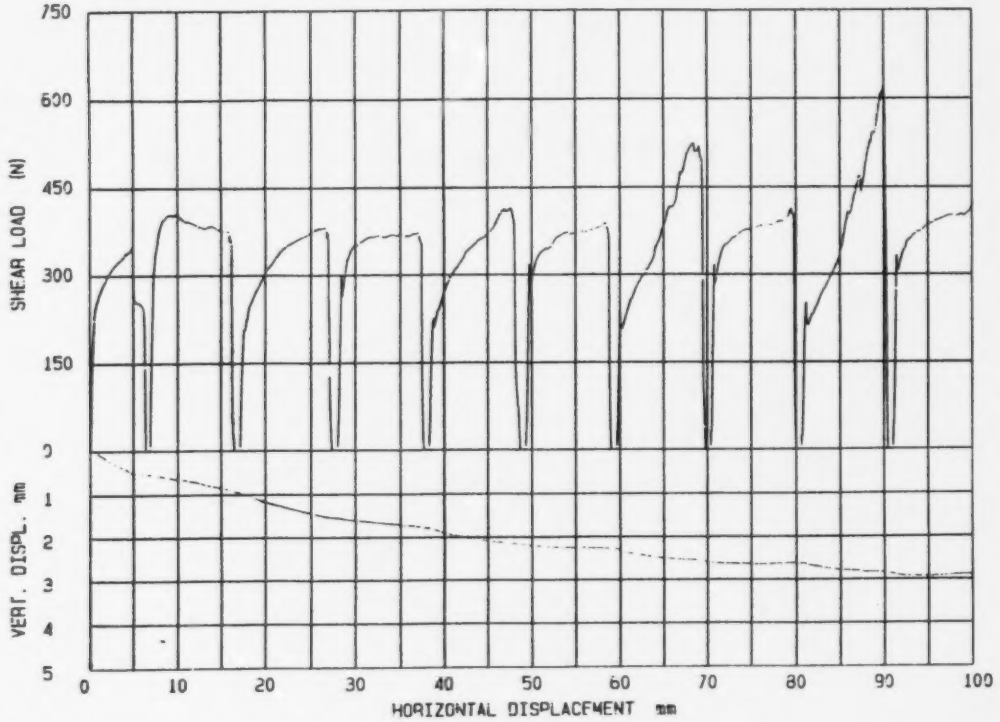
RESIDUAL DIRECT SHEAR TEST RESULTS



OLD MAN RIVER PA206202
EAST 1082 Sa 1A
NORMAL LOAD 1440 Newtons
NORMAL PRESSURE 400 kPa
60mm sq Shear Box
DISPLACEMENT RATE .012 mm/min

Alberta ENVIRONMENT	Project: OLDMAN RIVER DAM RESERVOIR RELATED WORKS		
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title: RESIDUAL DIRECT SHEAR TEST RESULTS		
Subconsultant: KLOHN LEONOFF LTD.	Approval	Date Of Issue	Revision Number / Dwg. No.

RESIDUAL DIRECT SHEAR TEST RESULTS



OLD MAN RIVER PA2C6202
WEST 1081 Sa 1K
NORMAL LOAD 1440 Newtons
NORMAL PRESSURE 400 kPa
60mm sq Shear Box
DISPLACEMENT RATE .012 mm/min

Alberta ENVIRONMENT

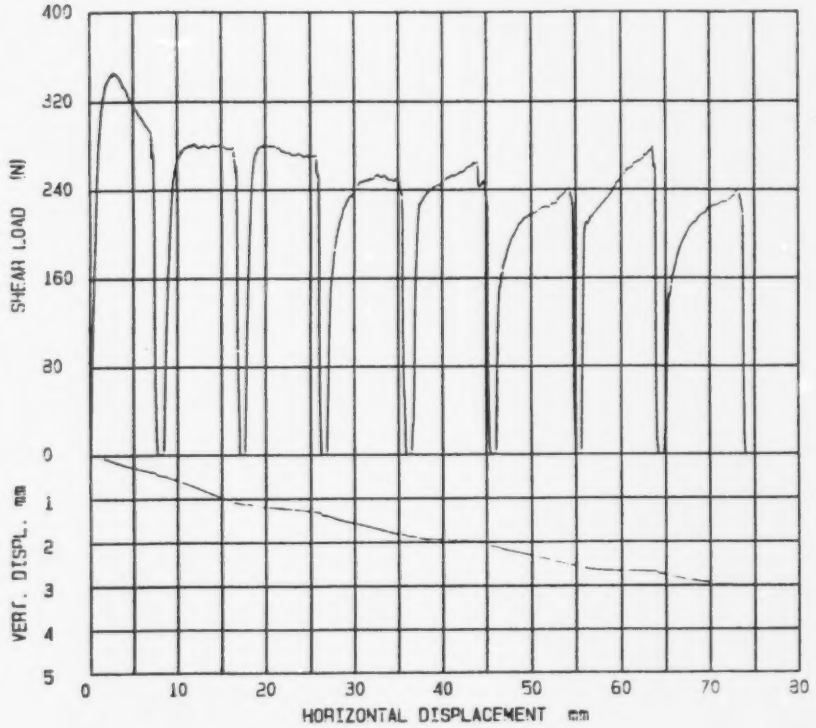
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.
Subconsultant

Project: OLDMAN RIVER DAM
RESERVOIR RELATED WORKS

Title

Approved	Date Of Issue	Revision Number	Dwg. No.

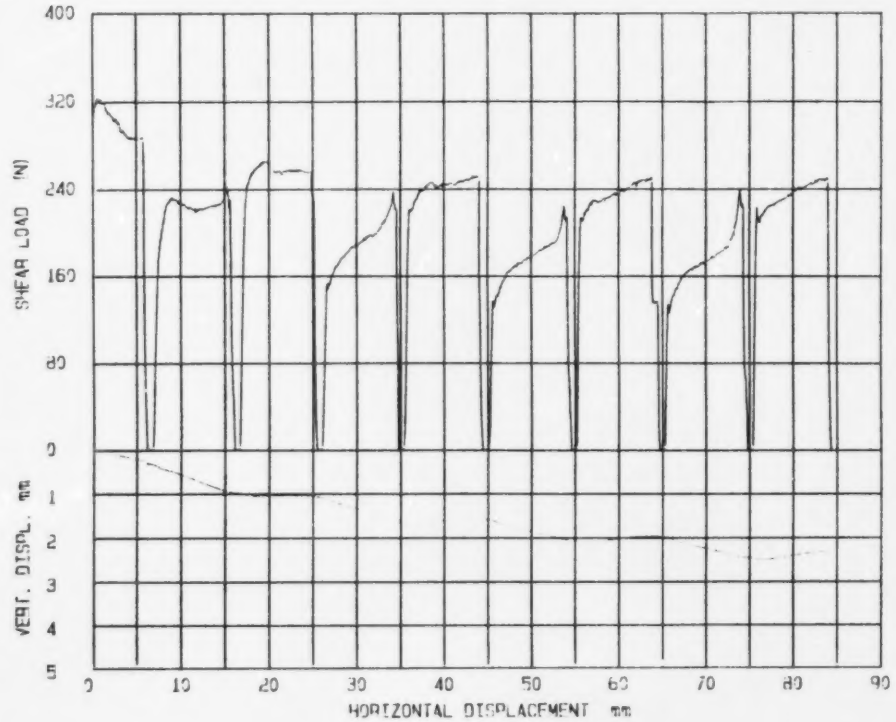
RESIDUAL DIRECT SHEAR TEST RESULTS



OLD MAN RIVER PA206202
FAST 1082 Sa 1A
NORMAL LOAD 720 Newtons
NORMAL PRESSURE 200 kPa
60mm sq Shear Box
DISPLACEMENT RATE .012 mm/min

Alberta ENVIRONMENT	Project: OLDMAN RIVER DAM RESERVOIR RELATED WORKS			
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title: RESIDUAL DIRECT SHEAR TEST RESULTS			
Subconsultant: KLOHN LEONOFF LTD.	Approved	Date Of Issue	Revision Number	Dwg. No.

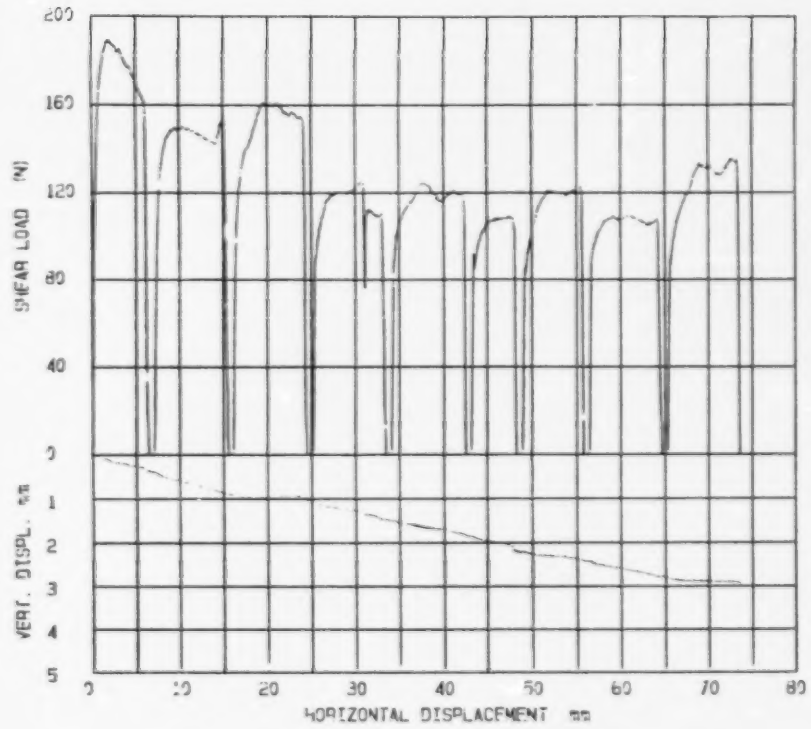
RESIDUAL DIRECT SHEAR TEST RESULTS



OLD MAN RIVER PA206202
FAST 10d2 Sa 1A
NORMAL LOAD 720 Newtons
NORMAL PRESSURE 200 kPa
60mm sq Shear Box
DISPLACEMENT RATE .012 mm/min

Alberta ENVIRONMENT	Project: OLDMAN RIVER DAM RESERVOIR RELATED WORKS			
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title: RESIDUAL DIRECT SHEAR TEST RESULTS			
Subconsultant: KLOHN LEONOFF LTD.	Approval	Date Of Issue	Revision Number	Dwg. No.

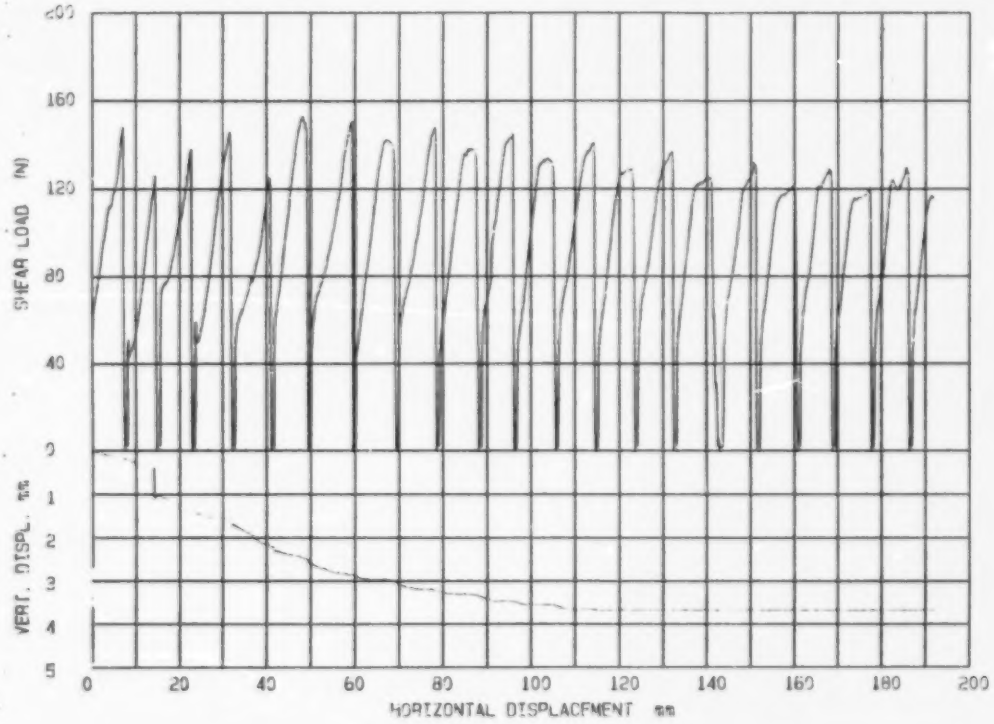
RESIDUAL DIRECT SHEAR TEST RESULTS



OLD MAN RIVER PA206202
EAST 1082 S4 1A
NORMAL LOAD 360 Newtons
NORMAL PRESSURE 100 kPa
60mm sq Shear Box
DISPLACEMENT RATE .012 mm/min

Alberta ENVIRONMENT	Project: OLDMAN RIVER DAM RESERVOIR RELATED WORKS			
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title: RESIDUAL DIRECT SHEAR TEST RESULTS			
Subconsultant: KLOHN LEONOFF LTD.	Approved	Date Of Issue	Revision Number	Dwg. No.

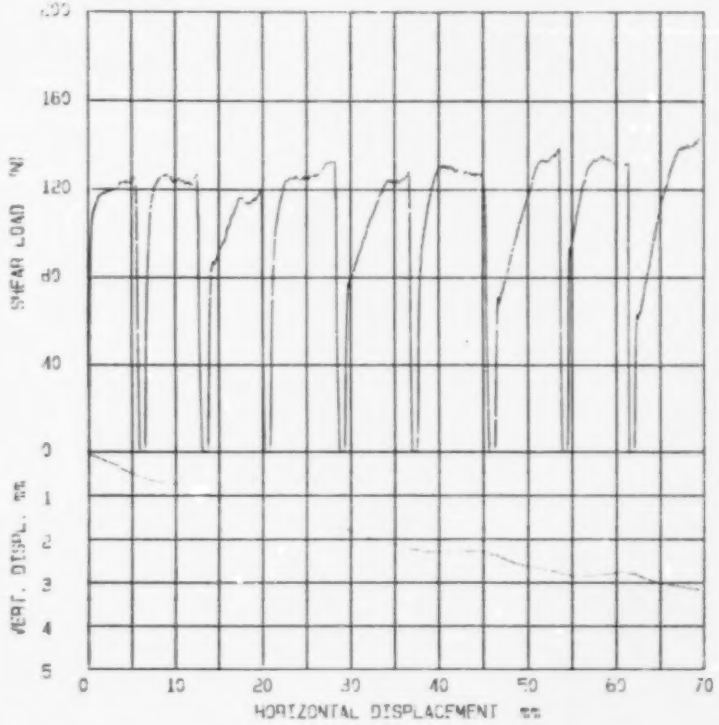
RESIDUAL DIRECT SHEAR TEST RESULTS



OLD MAN RIVER PA206204
FAST 1082 Sa 1A
NORMAL LOAD 360 Newtons
NORMAL PRESSURE 100 kPa
60mm sq Shear Box
DISPLACEMENT RATE .012 mm/min

Alberta ENVIRONMENT	Project: OLDMAN RIVER DAM RESERVOIR RELATED WORKS	
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title: RESIDUAL DIRECT SHEAR TEST RESULTS	
Subconsultant: KLOHN LEONOFF LTD.	Approved / Date Of Issue / Revision Number	Dwg. No.

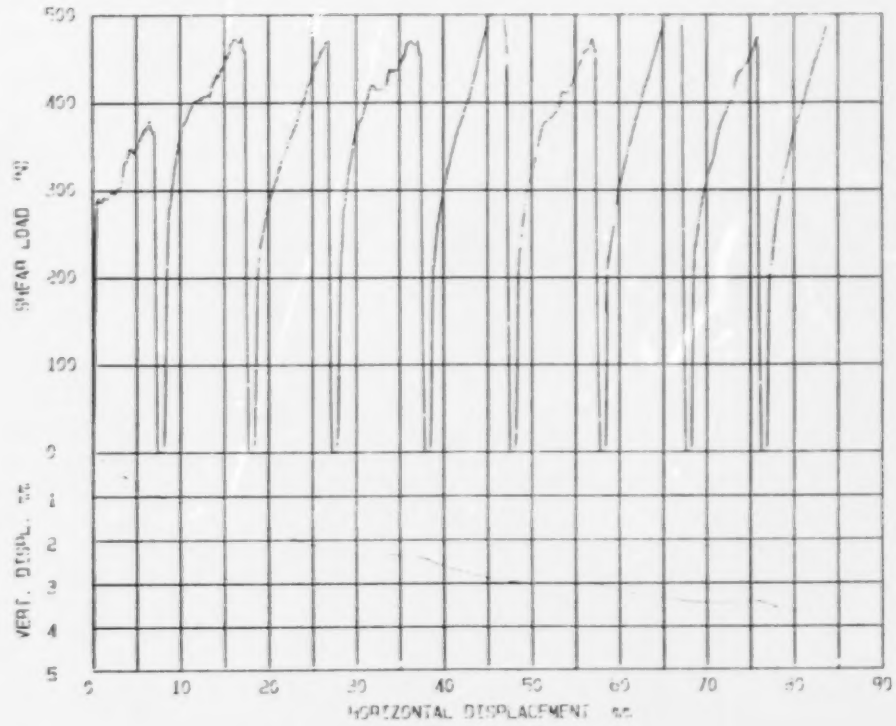
RESIDUAL DIRECT SHEAR TEST RESULTS



OLD MAN RIVER PA20bd2a
EAST 10H2 Sa 10
NORMAL LOAD 360 Newtons
NORMAL PRESSURE 100 kPa
60mm sq Shear Box
DISPLACEMENT RATE .012 mm/min

Alberta ENVIRONMENT	Project: OLDMAN RIVER DAM RESERVOIR RELATED WORKS			
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title: RESIDUAL DIRECT SHEAR TEST RESULTS			
Subconsultant: KLOHN LEONOFF LTD.	Approved	Date Of Issue	Revision Number	Dwg. No.

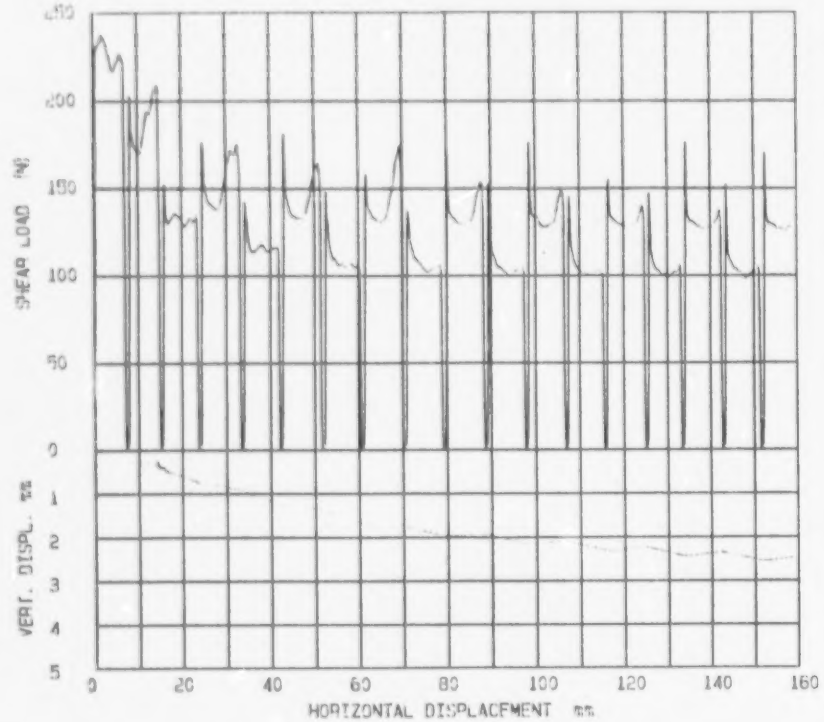
RESIDUAL DIRECT SHEAR TEST RESULTS



OLD MAN RIVER PA20b20c
EAST 10d8 Sn 1C
NORMAL LOAD 1440 Newtons
NORMAL PRESSURE 400 kPa
60mm sq Shear Box
DISPLACEMENT RATE .012 mm/min

Alberta ENVIRONMENT	Project: OLDMAN RIVER DAM RESERVOIR RELATED WORKS		
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title: RESIDUAL DIRECT SHEAR TEST RESULTS		
Subconsultant: KLOHN LEONOFF LTD.	Approved	Date Of Issue	Revision Number / Dwg. No.

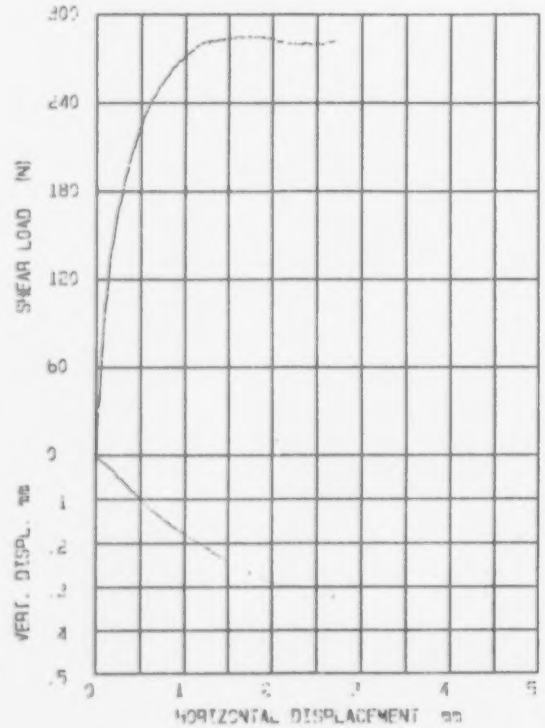
RESIDUAL DIRECT SHEAR TEST RESULTS



OLD MAN RIVER PA20b&20d
EAST 1082 Sa 10
NORMAL LOAD 720 Newtons
NORMAL PRESSURE 200 kPa
60mm sq Shear Box
DISPLACEMENT RATE .012 mm/min

Alberta ENVIRONMENT	Project: OLDMAN RIVER DAM RESERVOIR RELATED WORKS			
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title: RESIDUAL DIRECT SHEAR TEST RESULTS			
Subconsultant: KLOHN LEONOFF LTD.	Approved	Date Of Issue	Revision Number	Dwg. No.

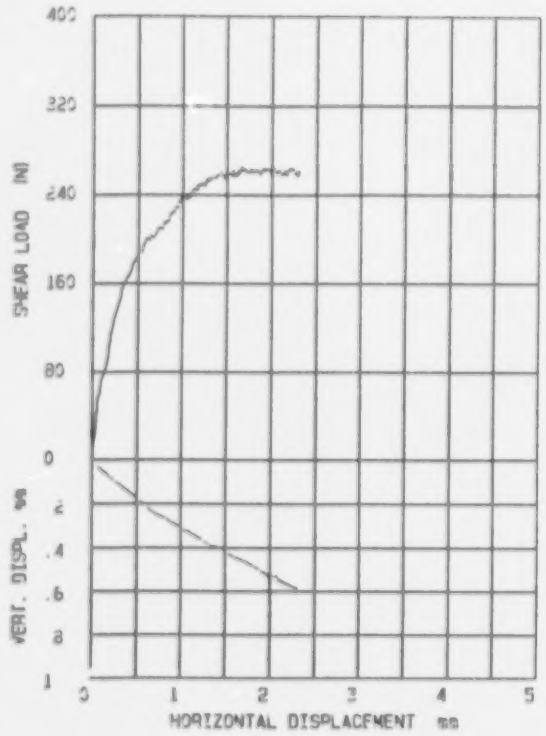
PEAK DIRECT SHEAR TEST RESULTS



OLD MAN RIVER PA206202
#EST 1081 Sa 1C
NORMAL LOAD 720 Newtons
NORMAL PRESSURE 200 kPa
DISPLACEMENT RATE .00096 mm/min
AREA 36 sq cm

Alberta ENVIRONMENT	Project: OLDMAN RIVER DAM RESERVOIR RELATED WORKS			
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title: RESIDUAL DIRECT SHEAR TEST RESULTS			
Subconsultant: KLOHN LEONOFF LTD.	Approved	Date Of Issue	Revision Number	Dwg. No.

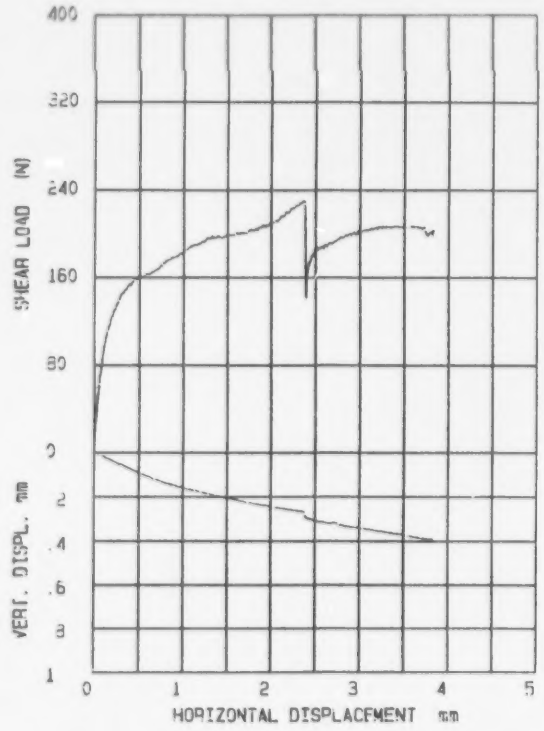
PEAK DIRECT SHEAR TEST RESULTS



OLD MAN RIVER PA206202
WEST 1981 Sh 1K
NORMAL LOAD 1440 Newtons
NORMAL PRESSURE 400 kPa
60mm sq Shear Box
DISPLACEMENT RATE .00096 mm/min

Alberta ENVIRONMENT	Project: OLDMAN RIVER DAM RESERVOIR RELATED WORKS			
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title: RESIDUAL DIRECT SHEAR TEST RESULTS			
Subconsultant: KLOHN LEONOFF LTD.	Approved	Date Of Issue	Revision Number	Dwg. No.

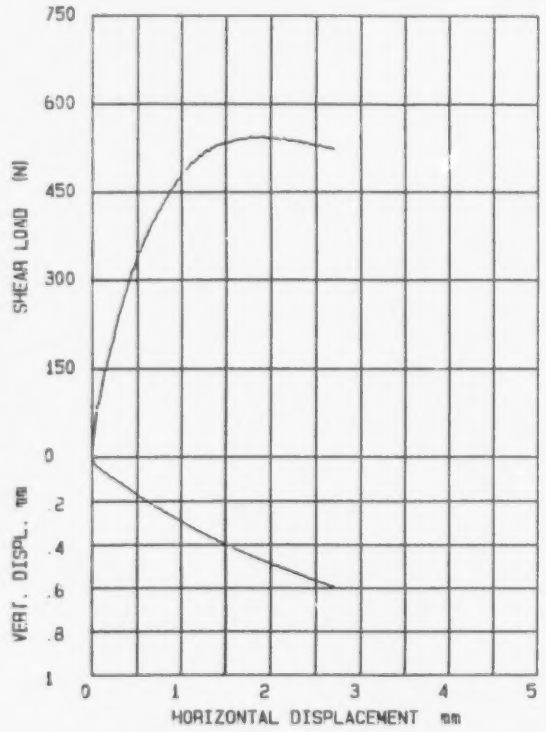
PEAK DIRECT SHEAR TEST RESULTS



OLD MAN RIVER PA206202
WEST 1081 Sa 1K
NORMAL LOAD 720 Newtons
NORMAL PRESSURE 200 kPa
60mm sq Shear Box
DISPLACEMENT RATE .00096 mm/min

Alberta ENVIRONMENT	Project	OLDMAN RIVER DAM RESERVOIR RELATED WORKS			
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title	RESIDUAL DIRECT SHEAR TEST RESULTS			
Subconsultant: KLOHN LEONOFF LTD.	Approved	Date Of Issue	Revision Number	Dwg. No.	

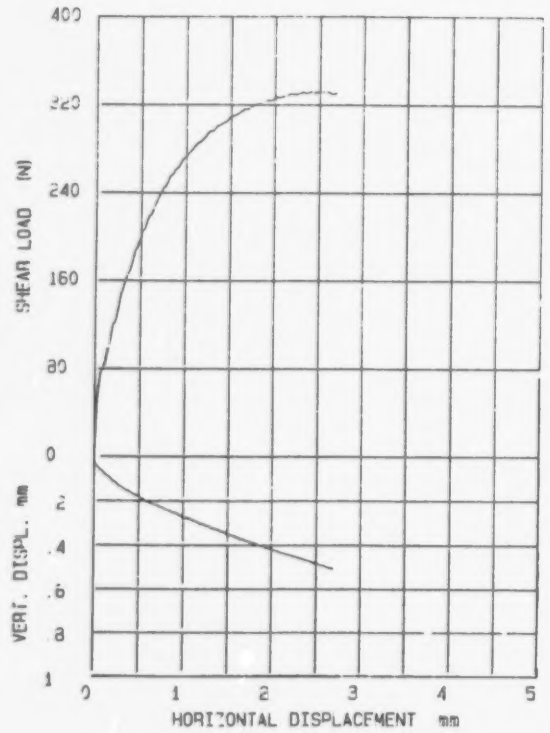
PEAK DIRECT SHEAR TEST RESULTS



OLD MAN RIVER PA206202
EAST 1082 Sa 1A
NORMAL LOAD 1440 Newtons
NORMAL PRESSURE 400 kPa
60mm sq Shear Box
DISPLACEMENT RATE .00096 mm/min

Alberta ENVIRONMENT	Project: OLDMAN RIVER DAM RESERVOIR RELATED WORKS			
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title: RESIDUAL DIRECT SHEAR TEST RESULTS			
Subconsultant: KLOHN LEONOFF LTD.	Approved	Date Of Issue	Revision Number	Dwg. No.

PEAK DIRECT SHEAR TEST RESULTS



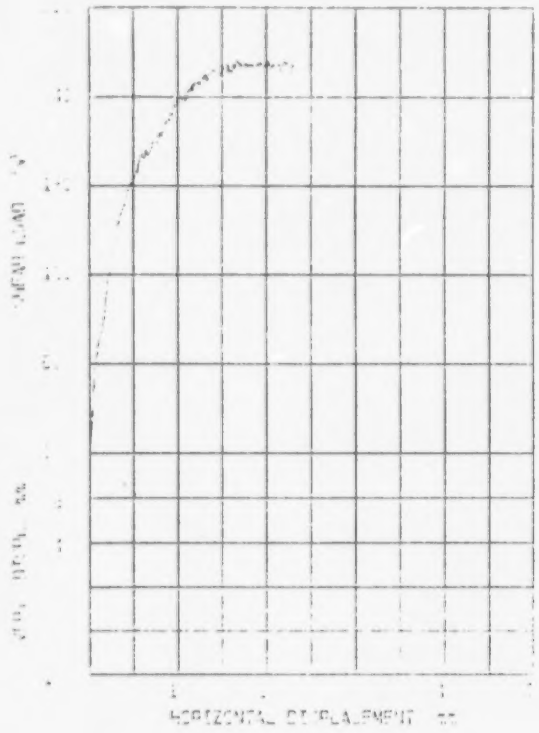
OLD MAN RIVER PA206202
EAST 1082 Sa 1A
NORMAL LOAD 720 Newtons
NORMAL PRESSURE 200 kPa
60mm sq Shear Box
DISPLACEMENT RATE .00096 mm/min

Alberta ENVIRONMENT	Proj.	OLDMAN RIVER DAM RESERVOIR RELATED WORKS		
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title	RESIDUAL DIRECT SHEAR TEST RESULTS		
Subconsultant: KLOHN LEONOFF LTD.	Approved	Date Of Issue	Revision Number	Dwg. No.

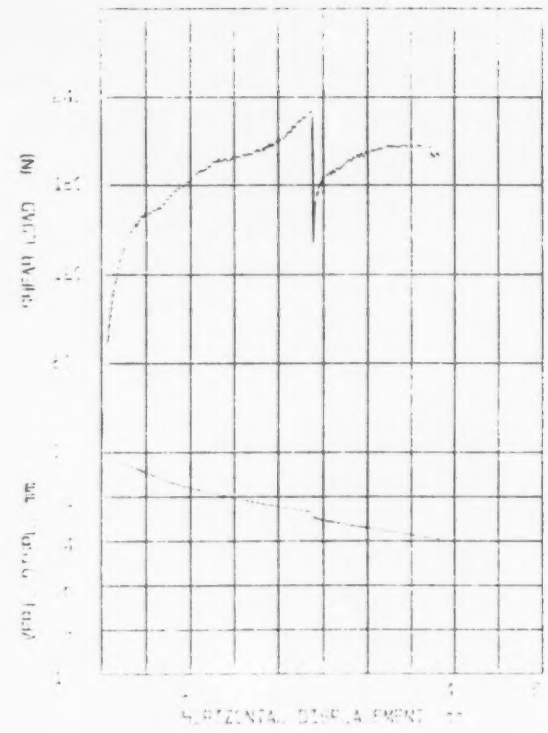
PEAK RIDE / MEAN [illegible] RESULTS

OLD MAN RIVER [illegible]
[illegible]
NORMAL LOAD [illegible]
NORMAL PRESSURE [illegible]
[illegible]
DISPLACEMENT RATE [illegible]

10°

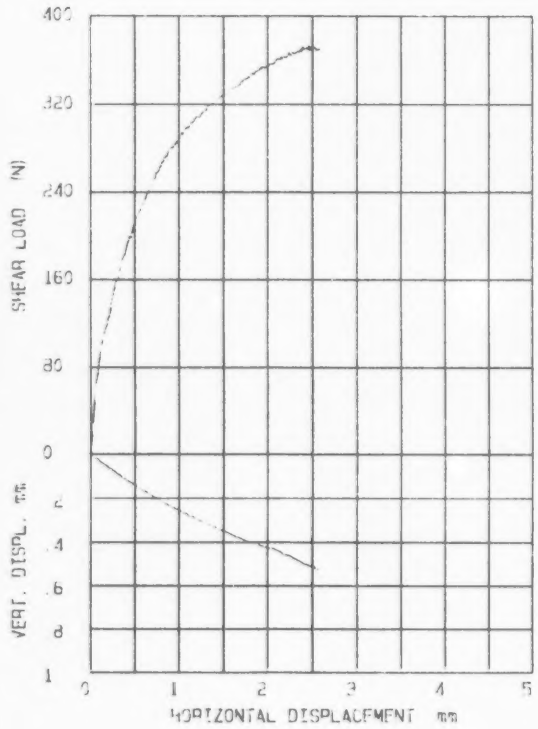


Alberta ENVIRONMENT	Project: OLDMAN RIVER DAM RESERVOIR RELATED WORKS			
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title: RESIDUAL DIRECT SHEAR TEST RESULTS			
Subconsultant: KLOHN LEONOFF LTD.	Approved	Date Of Issue	Revision Number	Dwg. No.



Alberta ENVIRONMENT	Project: OLDMAN RIVER DAM RESERVOIR RELATED WORKS
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title: RESIDUAL DIRECT SHEAR TEST RESULTS
Subconsultant: KLOHN LEONOFF LTD.	Approved / Date Of Issue / Revision Number / Dwg No

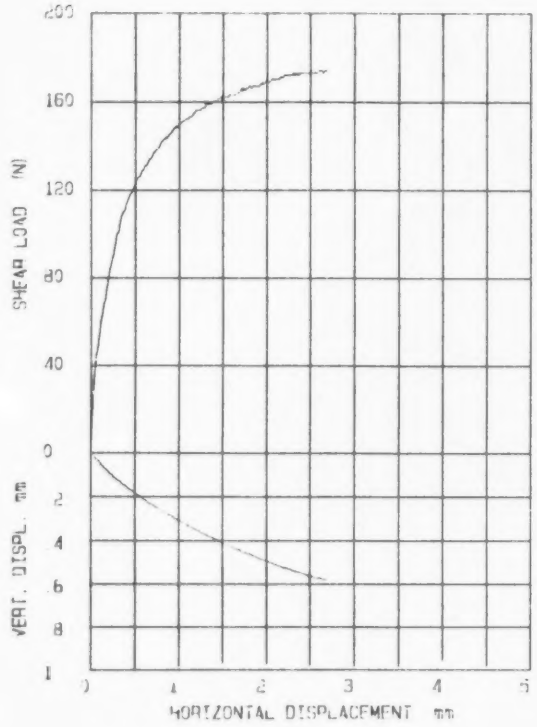
PEAK DIRECT SHEAR TEST RESULTS



OLD MAN RIVER PA206204
EAST 1082 Sa 1A
NORMAL LOAD 720 Newtons
NORMAL PRESSURE 200 kPa
60mm sq Shear Box
DISPLACEMENT RATE .0096 mm/min

Alberta ENVIRONMENT	Project: OLDMAN RIVER DAM RESERVOIR RELATED WORKS			
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title: RESIDUAL DIRECT SHEAR TEST RESULTS			
Subconsultant: KLOHN LEONOFF LTD.	Approved	Date Of Issue	Revision Number	Dwg. No.

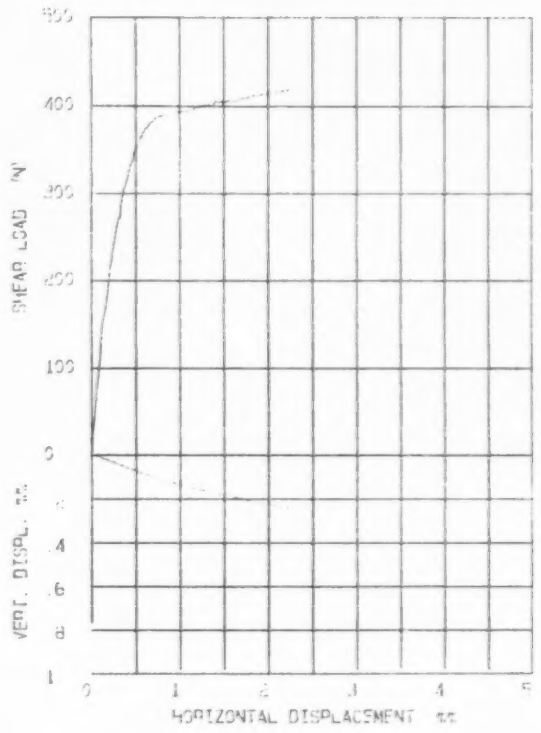
PEAK DIRECT SHEAR TEST RESULTS



OLD MAN RIVER PA206202
EAST 1082 Sa 1A
NORMAL LOAD 360 Newtons
NORMAL PRESSURE 100 kPa
60mm sq Shear Box
DISPLACEMENT RATE .00096 mm/min

Alberta ENVIRONMENT	Project: OLDMAN RIVER DAM RESERVOIR RELATED WORKS			
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title: RESIDUAL DIRECT SHEAR TEST RESULTS			
Subconsultant: KLOHN LEONOFF LTD.	Approved	Date Of Issue	Revision Number	Dwg. No.

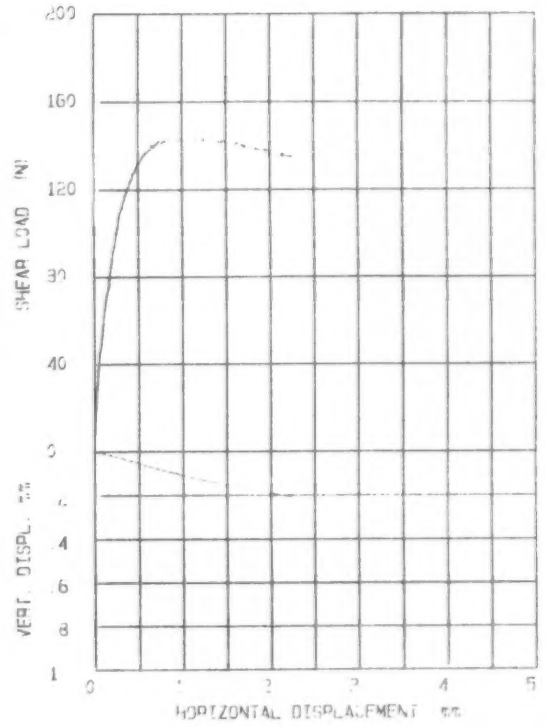
PEAK DIRECT SHEAR TEST RESULTS



OLD MAN RIVER PA[illegible]
EAST 1982 Sa 10
NORMAL LOAD 1440 Newtons
NORMAL PRESSURE 400 kPa
60mm sq Shear Box
DISPLACEMENT RATE 0.03 mm/min

Alberta ENVIRONMENT	Project: OLDMAN RIVER DAM RESERVOIR RELATED WORKS		
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title: RESIDUAL DIRECT SHEAR TEST RESULTS		
Subconsultant: KLOHN LEONOFF LTD.	Approved	Date Of Issue	Revision Number	Dwg No.

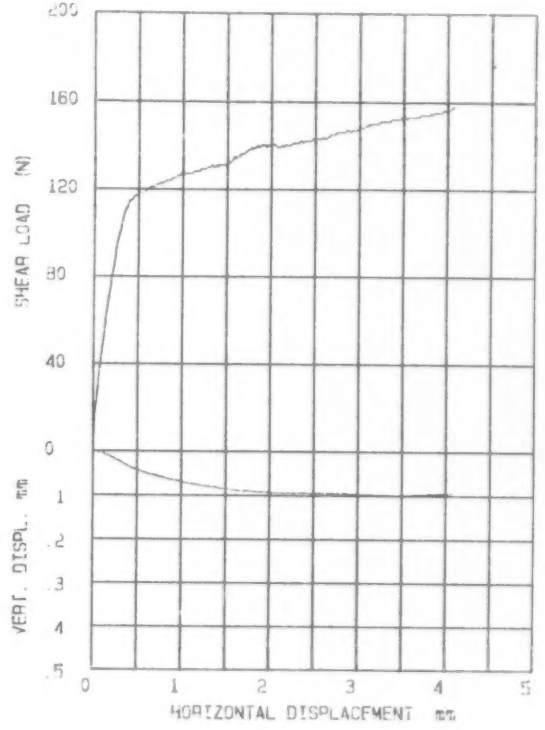
PEAK DIRECT SHEAR TEST RESULTS



OLD MAN RIVER PA206c2c
EAST 1082 Sa 1C
NORMAL LOAD 360 Newtons
NORMAL PRESSURE 100 kPa
60mm sq Shear Box
DISPLACEMENT RATE 00096 mm/min

Alberta ENVIRONMENT	Project: OLDMAN RIVER DAM RESERVOIR RELATED WORKS			
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title: RESIDUAL DIRECT SHEAR TEST RESULTS			
Subconsultant: KLOHN LEONOFF LTD.	Approved	Date Of Issue	Revision Number	Dwg. No.

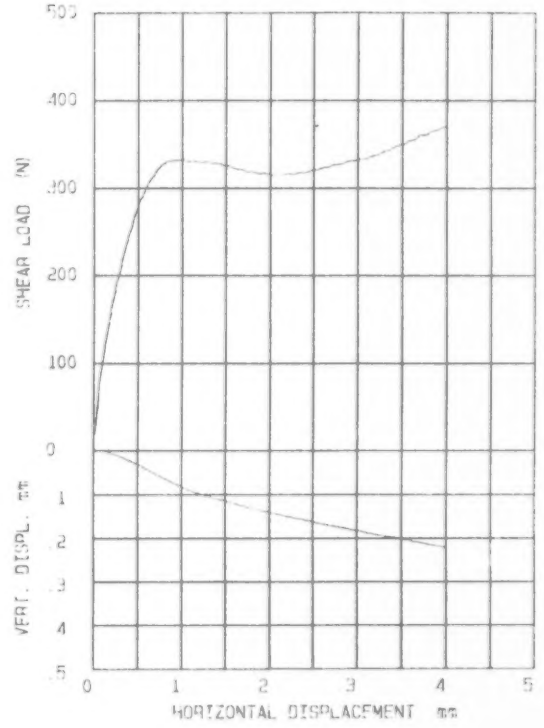
PEAK DIRECT SHEAR TEST RESULTS



OLD MAN RIVER PA206202
EAST 1082 Sa 1A
NORMAL LOAD 360 Newtons
NORMAL PRESSURE 100 kPa
60mm sq Shear Box
DISPLACEMENT RATE .0009b mm/min

Alberta ENVIRONMENT		Project	OLDMAN RIVER DAM RESERVOIR RELATED WORKS		
Prime Consultant STANLEY ASSOCIATES ENGINEERING LTD.		Title	RESIDUAL DIRECT SHEAR TEST RESULTS		
Subconsultant KLOHN LEONOFF LTD.	Approval	Date of Issue	Revision Number	Dwg. No.	

PEAK DIRECT SHEAR TEST RESULTS

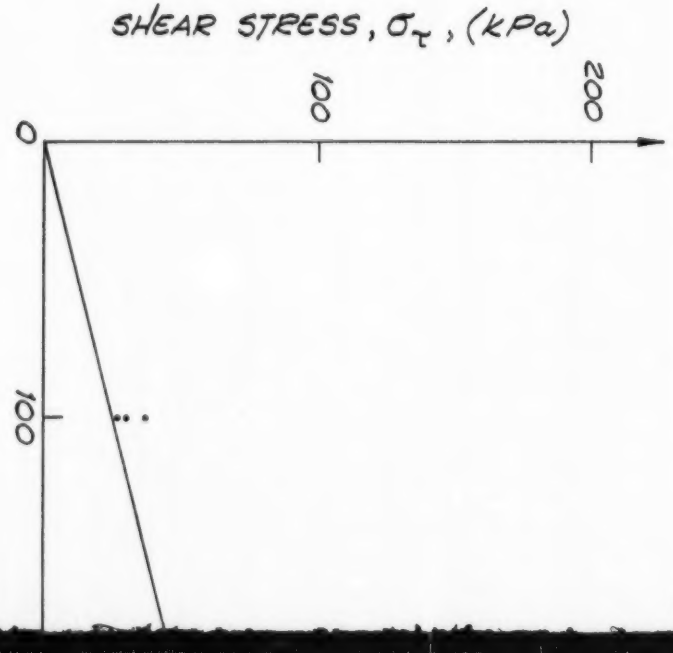


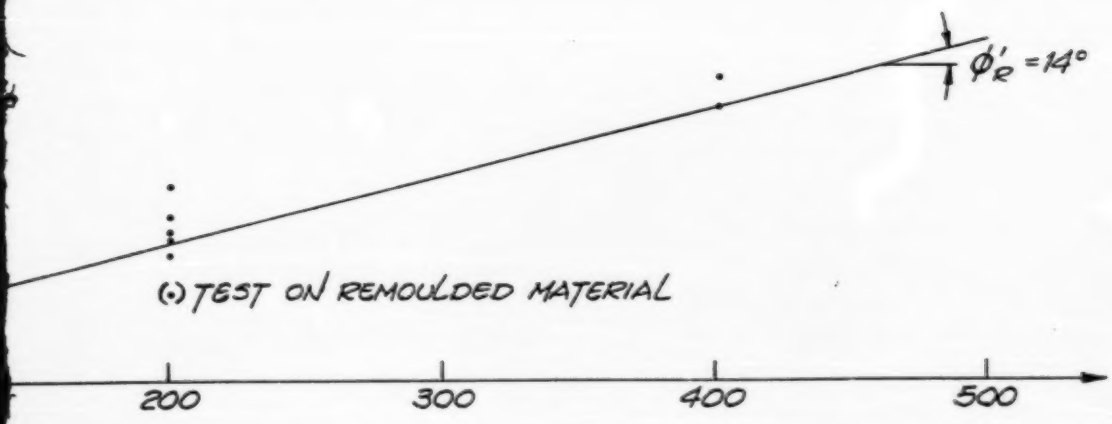
OLD MAN RIVER PA20b20z
FAST 1082 Sa 10
NORMAL LOAD 720 Newtons
NORMAL PRESSURE 200 kPa
60mm sq Shear Box
DISPLACEMENT RATE .00096 mm/sec

Alberta ENVIRONMENT	Project: OLDMAN RIVER DAM RESERVOIR RELATED WORKS		
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title: RESIDUAL DIRECT SHEAR TEST RESULTS		
Subconsultant: KLOHN LEONOFF LTD.	Approved	Date Of Issue	Revision Number / Dwg. No.

DRAWINGS

2062.100 - Test Hole Location Plan & Stratigraphic Section
2062.101 - Direct Shear Test Results
2062.102 - Proposed Stabilization Berms at CPR Bridge
2062.103 - Slope Stability Analysis West Abutment
2062.104 - Slope Stability Analysis East Abutment
2062.105 - CPR Bridge West Abutment Pier Excavation
2062.106 - CPR Bridge West Abutment Pier
2062.107 - CPR Bridge Anchor Details
2062.108 - Proposed Coulee Stabilization Berms

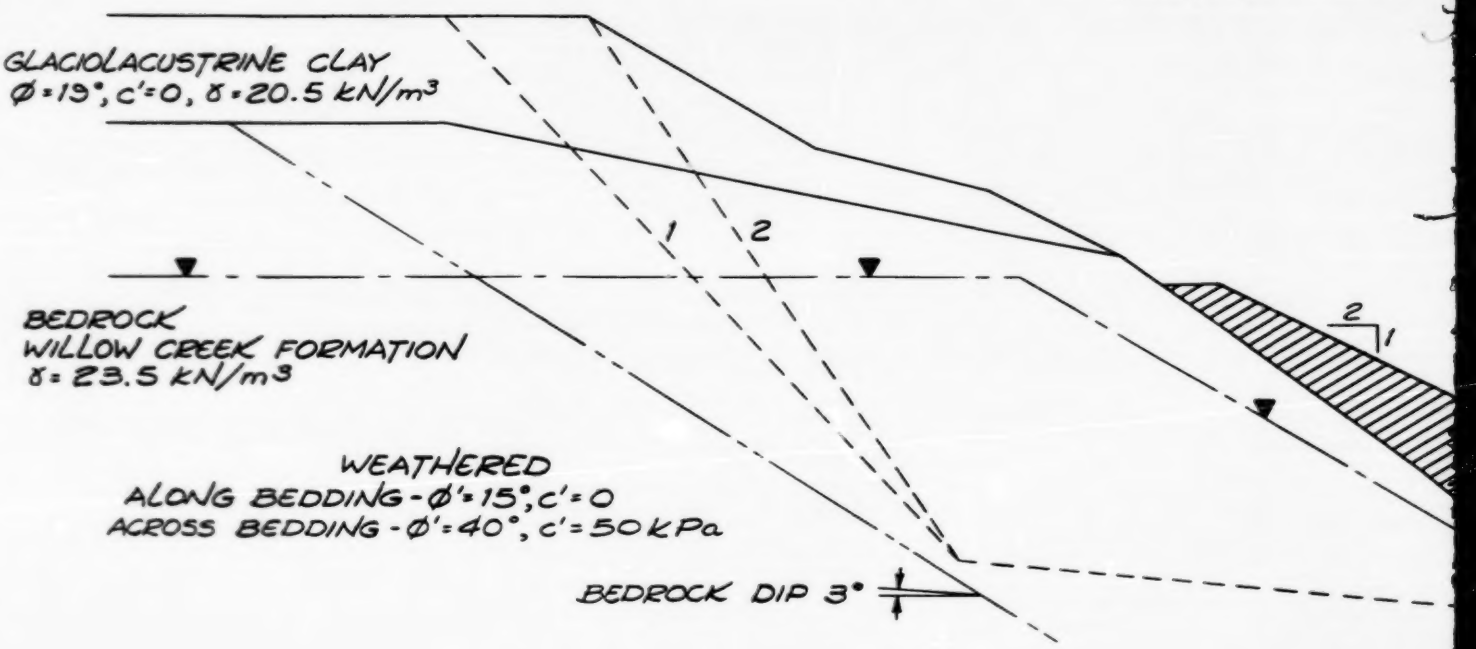

SHEAR STRESS, σ_τ, (kPa)
0
100
200
100



NOTE:
SOME POINTS REPRESENT TWO TEST RESULTS

Alberta ENVIRONMENT	Project: OLDMAN RIVER DAM RESERVOIR RELATED WORKS			
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title: DIRECT SHEAR TEST RESULTS			
Subconsultant: KLOHN LEONOFF LTD.	Approved	Date Of Issue: APRIL/87	Revision Number	Dwg. No.: 2062.101

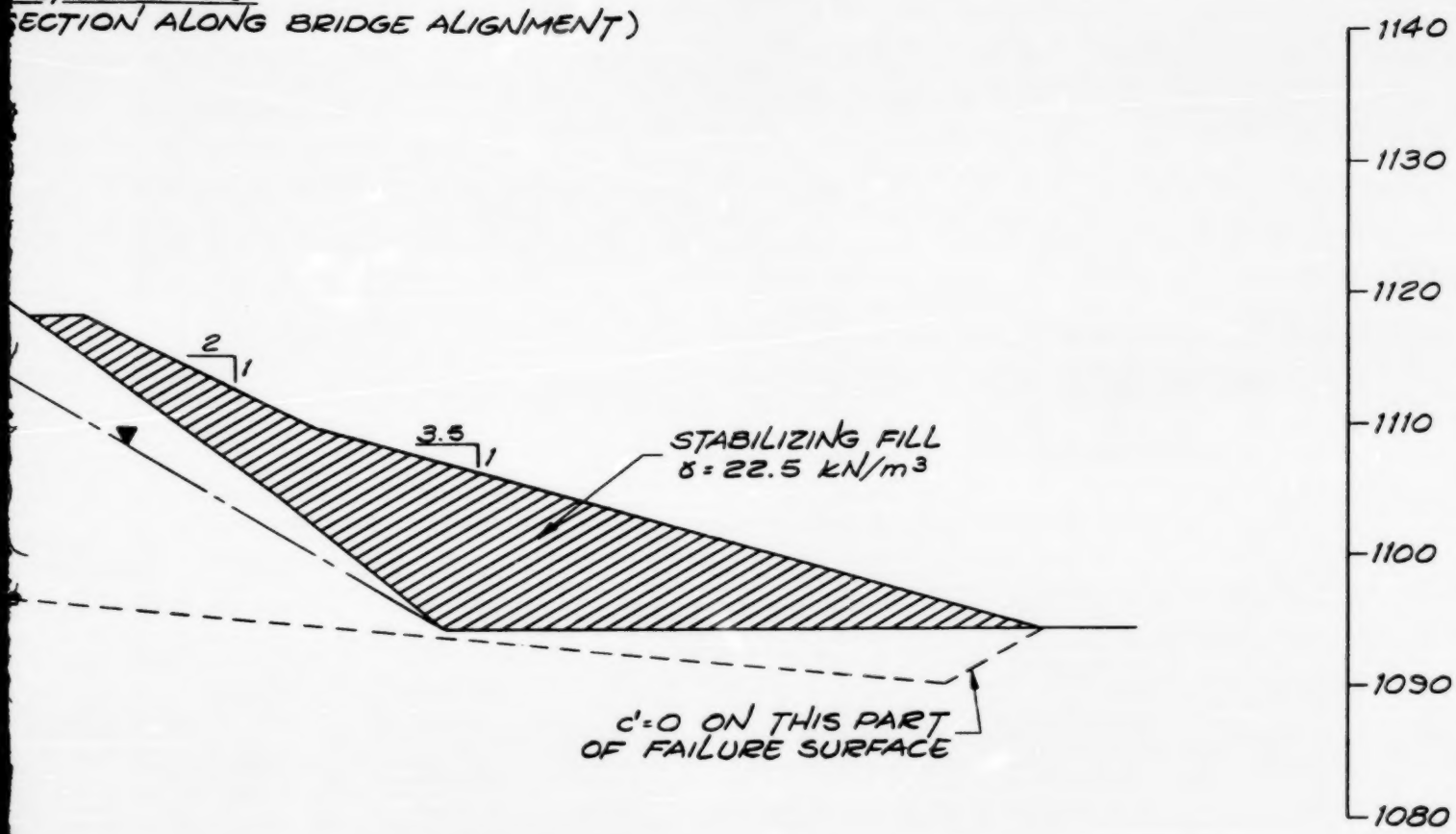
SECTION
WEST ABUTMENT OF
CPR BRIDGE OVER
CASTLE RIVER
(SECTION ALONG B



NOTES

BEDDING IN THE VICINITY OF THE WEST ABUTMENT HAS BEEN INTERPRETED AS DIPPING ALONG BRIDGE ALIGNMENT, AT ABOUT 3° INTO THE VALLEY. THE FAILURE PLANES HAVE BEEN CONSTRAINED TO FOLLOW ONE OF THE WEAKER SHEAR PLANES ENCOUNTERED IN LDH - WEST. A 3.5H:1V STABILIZING FILL IS REQUIRED TO PROVIDE AN ADEQUATE F.O.S.

ECTION
EST ABUTMENT OF
PR BRIDGE OVER
ASTLE RIVER
ECTION ALONG BRIDGE ALIGNMENT)

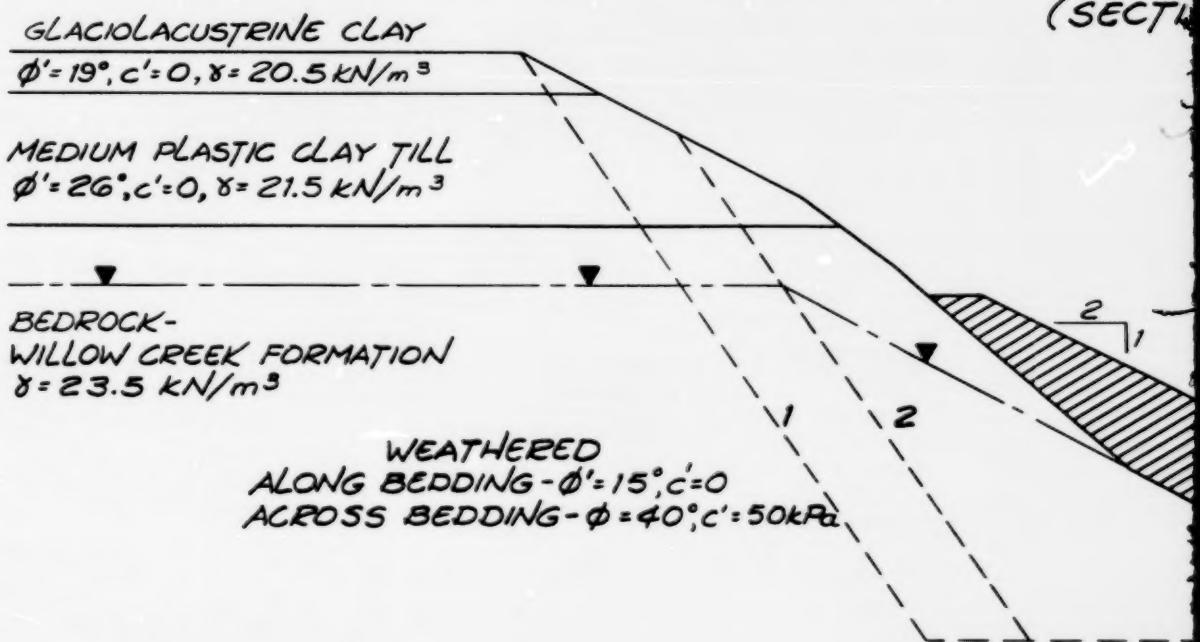


FAILURE PLANE	F.O.S.
1	1.43
2	1.42

BEEN
T, AT
E BEEN
PLANES
NG FILL

Alberta ENVIRONMENT	Project: OLDMAN RIVER DAM RESERVOIR RELATED WORKS			
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title: SLOPE STABILITY ANALYSIS - WEST ABUTMENT			
Subconsultant: KLOHN LEONOFF LTD.	Approved	Date Of Issue	Revision Number	Dwg. No. 2062.103

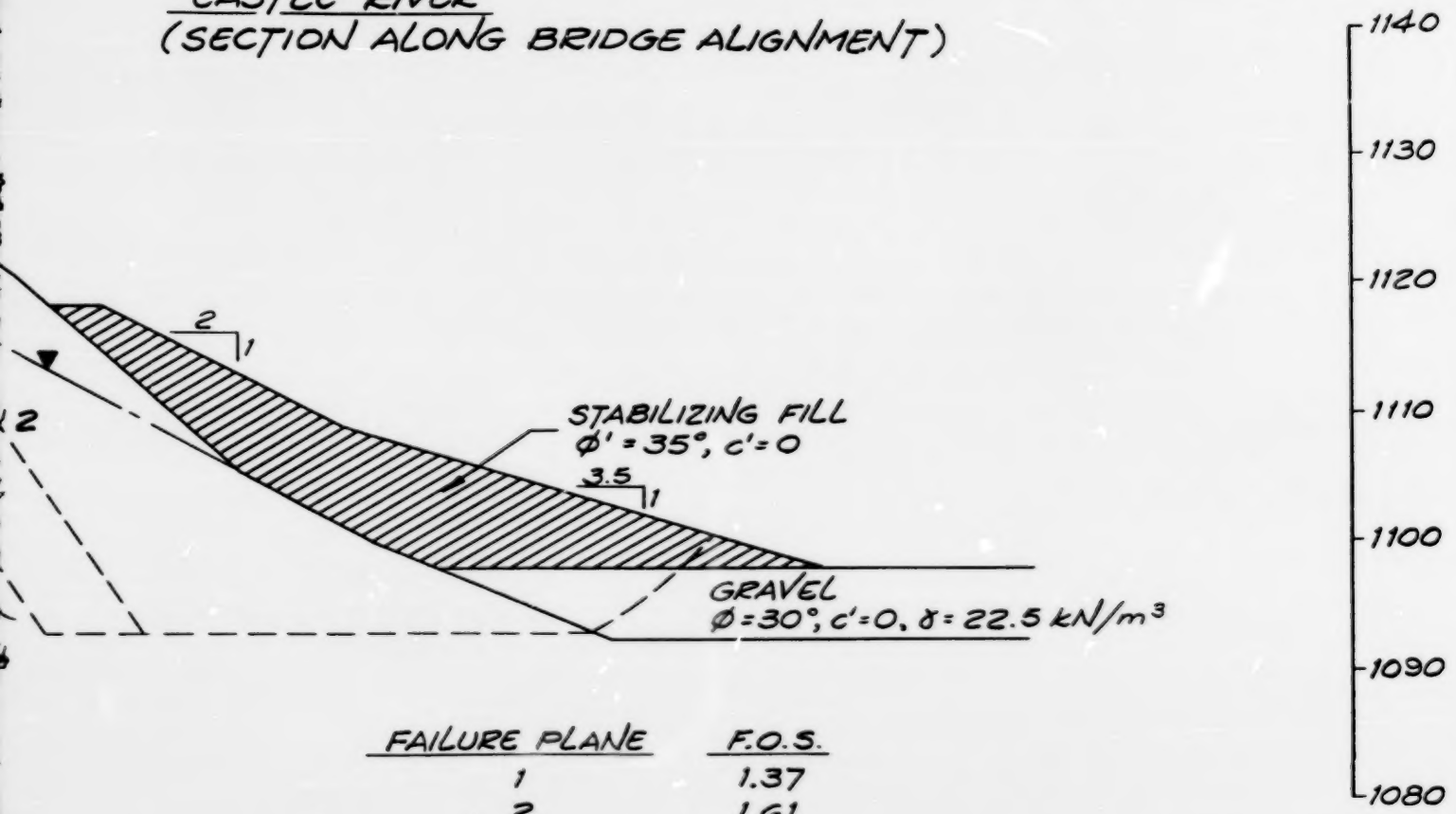
SECT
EAST
CPR
CAST
(SECT



NOTES

BEDDING IN THE VICINITY OF THE EAST ABUTMENT HAS BEEN INTERPRETED AS APPROXIMATELY HORIZONTAL ALONG BRIDGE ALIGNMENT. THE FAILURE PLANES HAVE BEEN CONSTRAINED TO FOLLOW ONE OF THE WEAKER SHEAR PLANES ENCOUNTERED IN LDH-EAST. A 3.5 H : 1V STABILIZING FILL IS REQUIRED TO PROVIDE AN ADEQUATE F.O.S.

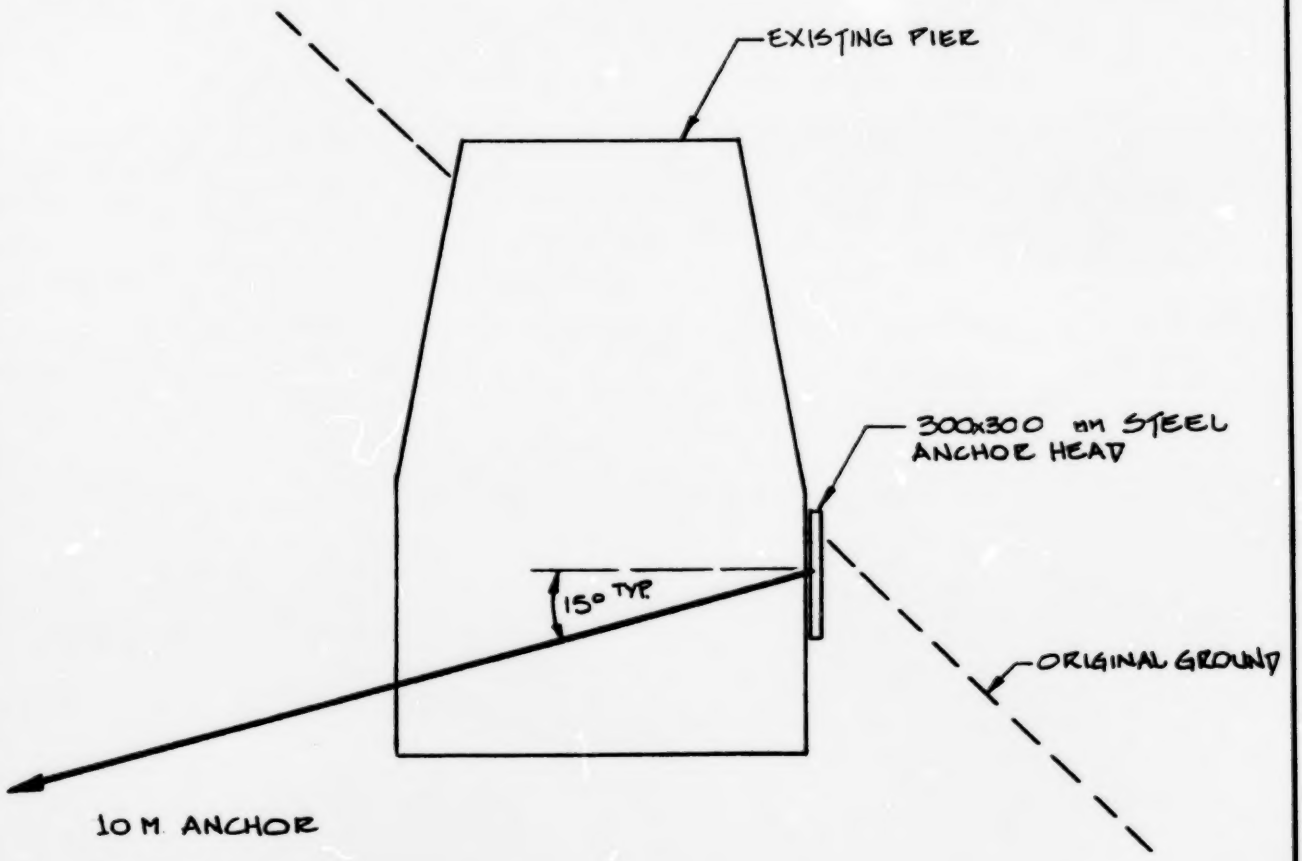
SECTION
EAST ABUTMENT OF
CPR BRIDGE OVER
CASTLE RIVER
(SECTION ALONG BRIDGE ALIGNMENT)



FAILURE PLANE	F.O.S.
1	1.37
2	1.61

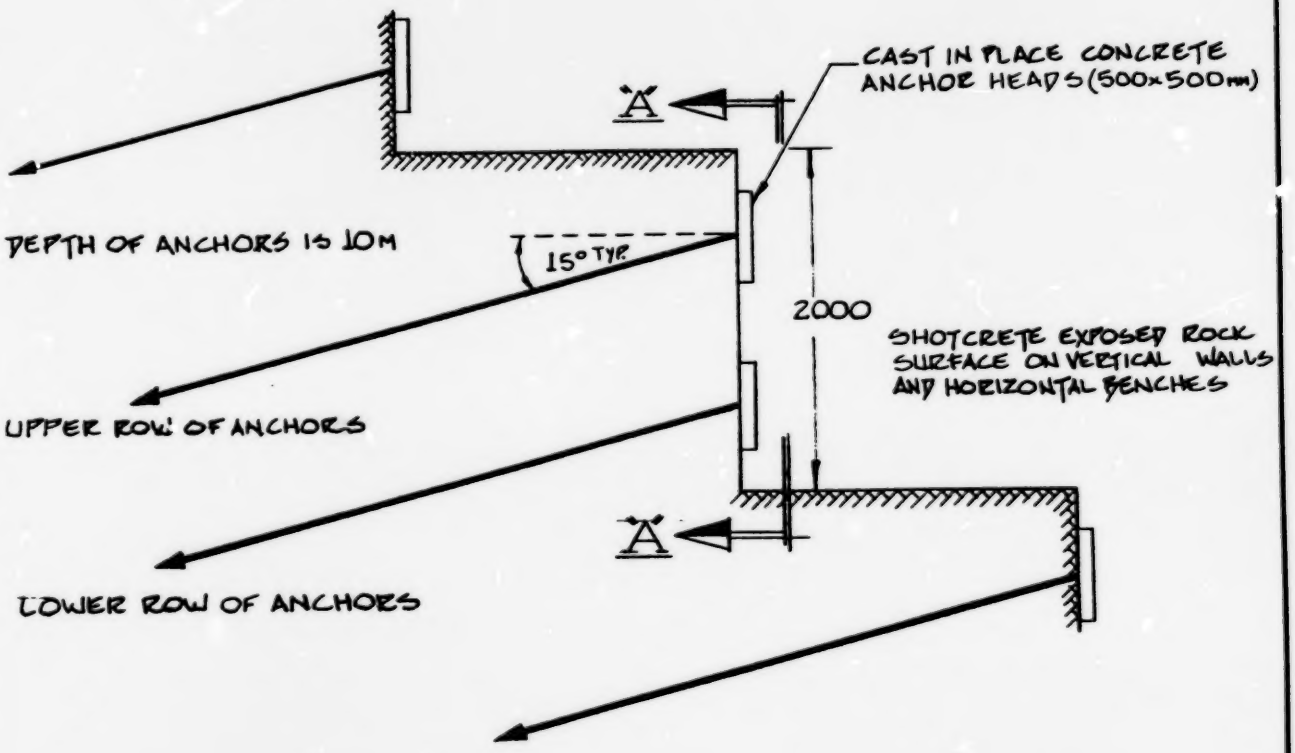
Alberta ENVIRONMENT	Project: OLDMAN RIVER DAM RESERVOIR RELATED WORKS			
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title: SLOPE STABILITY ANALYSIS - EAST ABUTMENT			
Subconsultant: KLOHN LEONOFF LTD.	Approved	Date Of Issue	Revision Number	Dwg. No. 2062.104

Alberta ENVIRONMENT	Project: OLDMAN RIVER DAM RESERVOIR RELATED WORKS			
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title: CPR BRIDGE WEST ABUTMENT PIER EXCAVATION			
Subconsultant: KLOHN LEONOFF LTD.	Approved	Date Of Issue: APRIL 87	Revision Number: PA 2062	Dwg. No.: 2062-105

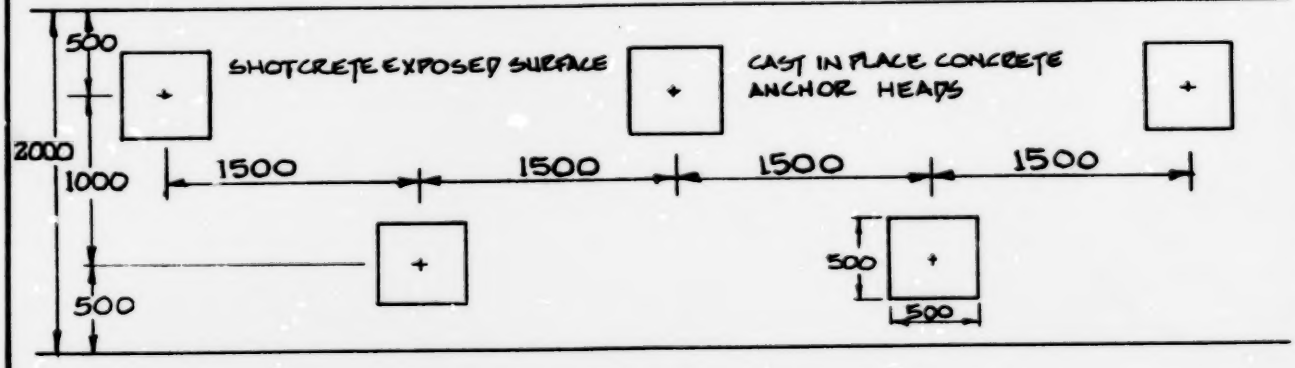


REF. DWG 2062-105

Alberta ENVIRONMENT	Project: OLDMAN RIVER DAM RESERVOIR RELATED WORKS			
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title: CPR BRIDGE WEST ABUTMENT			
Subconsultant: KLOHN LEONOFF LTD.	Approved	Date Of Issue: APRIL-87	Revision Number: PA2062	Dwg. No.: 2062-106



SECTION OF EXPOSED ROCK FACE WITH ANCHORS
(REF DWG 2062-105)



SECTIONAL ELEVATION 'A'-'A'

NOTE: ALL DIMENSIONS IN MM.

Alberta ENVIRONMENT	Project: OLDMAN RIVER DAM RESERVOIR RELATED WORKS			
Prime Consultant: STANLEY ASSOCIATES ENGINEERING LTD.	Title: CPR BRIDGE ANCHOR DETAILS			
Subconsultant: KLOHN LEONOFF LTD.	Approved	Date Of Issue: APRIL 87	Revision Number: PA 2062	Dwg. No.: 2062 107

REPORT

OLDMAN RIVER DAM - RESERVOIR RELATED WORKS

HIGHWAY NO. 3 CROSSING

GEOTECHNICAL ASSESSMENT

for

STANLEY ASSOCIATES ENGINEERING LTD.

PA 2062

June 1987

KLOHN LEONOFF

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LIST OF DRAWINGS

2062.301 Test Hole Location Plan & Stratigraphic Section
2062.302 Highway No. 3 Stability Analyses
2062.303 Proposed Stability Berms at Highway No. 3 Bridge

1.0 INTRODUCTION

The purpose of the geotechnical investigation at the Highway No. 3 bridge over the Castle River is to assess the impact of the reservoir on the stability of the bridge abutments, piers and west approach fill and if necessary recommend methods of stabilizing the structure. At F.S.L. the reservoir will be approximately 10 m deep at this location. The induced pore water pressures in the valley slopes and embankment fill will, upon rapid reservoir drawdown, decrease the stability.

Investigation for the Highway No. 3 bridge was conducted in stages. Reconnaissance and subsequent geological mapping of the crossing area were carried out to provide a preliminary assessment of the site conditions such as soil and rock stratigraphy and existing slope stability. The bridge 'as built' drawings provided by Alberta Transportation were reviewed. Test hole drilling was carried out in the highway ditch adjacent to the east abutment (test hole 85-7) and on top of the approach fill adjacent to the west abutment (test hole 85-8). Test hole 85-7 provided data for assessment of the stability of the east abutment and slope. Test hole 85-8 provided data for assessment of the embankment fill stability. A survey determined locations and elevations of each test hole, as well as bedrock outcrops on the east valley slope.

2.0 EXISTING CONDITIONS

The Highway No. 3 bridge crosses the Castle River in the SE 1/4 11-7-1-5 and SW 1/4 12-7-1-5. At this location the river channel flows against the east side of the valley in a northerly direction, at approximately elevation 1109 m.

The east side of the valley, upstream of the bridge, is undercut on the outside of a river bend resulting in a slope gradient of about 60°. Bedrock is exposed below elevation 1120 m with clay till above

the bedrock surface. Beneath the east abutment sand and gravel fill has been placed at a slope of 2 horizontal on 1 vertical and the base of the slope protected with riprap. The crest of the valley slope at the bridge is at elevation 1140 m, above which the ground rises gradually eastward to about 1160 m.

The west side of the valley slope has an upland elevation of approximately 1163 m. There is an ancient river terrace, 150 m to 200 m wide, between elevation 1130 and 1140 m. The slope then drops at a gradient of 30° to 35° to a floodplain terrace which is approximately 200 m wide at the bridge. The highway crosses the floodplain on an embankment fill to the edge of the existing river channel. The embankment fill is approximately 15 m high with side slopes of approximately 2.5 horizontal on 1 vertical. The interior slope at the bridge abutment was constructed at 2 horizontal on 1 vertical and the base of the slope protected with riprap. 'As built' information indicates that most of the embankment fill is clay probably obtained from road approach cuts. A zone of sand and gravel fill was placed in the embankment, underlying the west abutment. Drawing No. D2062-301 shows a location plan and profile of the highway bridge crossing.

The 'as built' information indicates the bridge abutments are founded on steel H piles driven to refusal in the underlying bedrock. The bridge structure between abutments is supported on three single concrete piers. The outer piers, situated near the toe of the slope, are also supported on steel H piles. The central pier, in the river channel, is supported directly on bedrock, with a surrounding rock apron.

3.0 TEST HOLE RESULTS

To assess the east abutment stability, test hole 85-7 was drilled adjacent to the abutment in the ditch south of the highway. Test hole 85-7 was cored to the depth of 40 m. Test hole 85-8 was drilled through the approach fill, close to the west abutment, to a depth of 33 m.

Bedrock core was logged in the field. Selected soil samples of the overburden and bedrock core were tested to determine moisture contents, Atterberg Limits, and unit weight. A triaxial test was carried out on a sample of the clay fill from test hole 85-8. The test hole logs are presented in Appendix I.

4.0 SITE GEOLOGY

The regional geology is described in detail in the report entitled "Oldman River Dam Reservoir Boundary Study", dated December 1986.

The two drill holes at the bridge crossing and geological mapping of exposures, primarily on the east side of the river, indicates that the bedrock belongs to the Willow Creek formation. The formation is comprised of interbedded claystones, siltstones and sandstones. Test hole 85-7 on the east side of the river indicates primarily claystones and siltstones to an elevation close to riverbed level. Below riverbed level the formation alternates between sandstones and siltstones. Test hole 85-8, at the west abutment, encountered claystone at about riverbed level and then alternated between sandstone, siltstone and claystone to the bottom of the hole.

The claystone is the weakest rock of the Willow Creek Formation with both drill holes indicating numerous bedding plane shear zones.

Since only two holes were drilled at the site, one on each abutment, the bedding dip angle could only be estimated from mapping. The mapping on the east side of the valley suggests a bedding dip angle of 14° in the approximate direction N50°E.

5.0 PARAMETER SELECTION AND STABILITY ANALYSES

The study of the stability of the slopes around the reservoir included triaxial tests on the overburden and direct shear tests on samples of the weak bedrock seams. The parameters chosen for

analyses of the stability of the slopes at the Highway No. 3 crossing are presented on the Table 1. Details on the selection of the parameters are presented in the report entitled "Oldman River Dam Reservoir Boundary Study", dated December 1986.

The shear strength chosen for bedding planes in the Willow Creek formation, 13°, is the value used for all slopes around the reservoir, except the slopes at the CPR crossing. A higher value, 15°, was obtained from a detailed investigation at the CPR crossing. It was deemed inappropriate to assume the higher value at this time as the state of knowledge of the rock and bedding plane dip angles is limited at the Highway No. 3 crossing.

TABLE 1
SUMMARY OF MATERIAL PROPERTIES
USED IN STABILITY ANALYSES

	Effective Friction Angle Ø' (deg.)	Effective Cohesion c' (kPa)	Bulk Density (kN/m^3)
FILL			
Free Draining Gravel	35	0	22.5
Clay	19	0	20.5
OVERBURDEN			
Glaciolacustrine Clay	19	0	20.5
Medium Plastic Clay Till	26	0	21.5
Gravel	30	0	22.5
WILLOW CREEK FORMATION BEDROCK			
Along Bedding	13	0	23.5
Cross Bedding (weathered)	40	50	23.5
Cross Bedding (unweathered)	40	150	23.5

Several assumptions are made regarding pore water pressures in the slopes. The natural slopes in bedrock are assumed drained at the face of the slope within a strip 10 m wide at F.S.L. and zero at the drawdown level. This partial drainage is assumed to occur in the fractured weathered rock but not in thick overburden. Pore water pressures after rapid drawdown will be zero in free draining gravel fill.

A computer program using the Janbu method of computing stability along a composite failure surface was used to analyze the abutment and adjacent coulee slopes. A factor-of-safety of 1.2 would normally be sufficient for the case of rapid reservoir drawdown, where the probability of it occurring is infrequent. However, operation of the Oldman River Dam Reservoir may see the water level at the Highway No. 3 bridge drop significantly on an annual basis. A higher factor-of-safety was therefore considered appropriate and has been set at 1.35.

6.0 ABUTMENT AND APPROACH FILL STABILITY

6.1 Abutment Stability

The steep slope at the east abutment is presently buttressed by a sand and gravel fill with a slope gradient of 2 horizontal on 1 vertical. Based upon the parameters discussed above a larger fill is required to stabilize the abutment under conditions of rapid drawdown. The analyses to date indicates that the berm should have a minimum top width of 3 m and a slope gradient of 3 horizontal on 1 vertical. The top of berm should be at elevation 1119 m. Compacted free draining sand and gravel should be used for berm construction.

In order to stabilize the interior slope of the west abutment a larger berm is required than proposed for the east abutment. The free draining gravel berm should be a minimum of 10 m wide at the top with a slope gradient of 3 horizontal on 1 vertical. The top of berm under the bridge should be at elevation 1119 m.

The sketch on Drawing No. 2062.302 shows the assumptions made in the analyses of the east and west abutments. Drawing No. 2062.303 shows the plan and profile of the stabilization works proposed.

6.2 Approach Fill Stability

Except for the sand and gravel fill placed at the west abutment, the majority of the approach fill appears to be comprised of clay which has a much lower strength than the sand and gravel at the abutment. Stability analyses indicates that a berm with a top width of 10 m and side slopes of 3 horizontal on 1 vertical will be required. Because the clay fill will not drain quickly under conditions of rapid drawdown, the berm must extend to Elevation 1122 m. The top of the berm must transition from an Elevation of 1119 m at the abutment to Elevation 1122 m along the approach fill. Drawing No. 2062.303 shows a plan and profile of the proposed berms.

6.3 Slope Protection

The interior stabilizing berms at the bridge will significantly reduce the cross section of the channel under the bridge thereby creating a condition of high velocities under low river flows. Protection of the berms from erosion and of the center pier from scour must be carefully reviewed during final design.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are made from the study to date.

1. The bedrock at the Highway No. 3 crossing belongs to the Willow Creek formation. A bedding dip angle of 14° in the direction N50°E has been used for the present study. However, additional drill hole data is required for final design in order to better define the bedding dip angles and direction across the valley. Once the bedding dip data has been determined a sensitivity

analysis should be done comparing a bedding strength of 13° versus 15°. If a higher strength indicates a potential cost saving for stabilization of the crossing then a detailed investigation with large diameter holes (LDH's) would be warranted.

2. Based upon present data buttress fills of free draining gravel are required at both abutments and along the side slopes of the approach fill.

3. Due to anticipated high flow velocities under the bridge, protection of the berms and center pier must be carefully analyzed during final design.

PERMIT TO PRACTICE
KLOHN LEONOFF LTD.
Signature
Date
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

Yours very truly,

KLOHN LEONOFF LTD.

DONALD M. DAVISON, P. Eng.
Vice President, Alberta Region

DMD/sh

APPENDIX I

Test Hole Logs

Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD.

SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 8

SHEET 1 of 7

CONTRACTOR(S) / DRILL RIG(S): B: SDS Drilling - Mayhew 1000

RIG No. ____ DEPTH(m) ____ DATE ____ HOLE DIAM. ____ TOP CASING A (El.) ____

RIG No. B DEPTH(m) 33.2 DATE Sep 24-27/85 CORE DIAM. 76mm TOP CASING B (El.) ---

LOCATION: SW 12-7-1-W5

COORDINATES: 5489449.0 N

-1607.1 E

INITIAL DIP: VERTICAL

ELEVATIONS: GROUND SURFACE: 1128.7m

ROCK SURFACE: 1106.9m

BOTTOM OF HOLE: 1095.5m

DEPTH ELEV (m)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE STATE	SAMPLE No.	PENETRATION TEST (Blows/0.15m) X - STANDARD PENETRATION	UNCONFINED COMPRESSION kPa; PLASTIC LIMIT, WATER CONTENT, LIQUID LIMIT	UNIT WEIGHT (kN/m³)	COHESION (kPa)	ANGLE OF SHEARING RESISTANCE φ' (Deg)	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY (cm/sec)	PARTICLE SIZE (%)
0.00					10 20 30 40	100 200 300 400; 10 20 30 70 99%						
0.04	ASPHALT											
1128.6												
	SAND and GRAVEL (FILL)											
1.00												
1127.7				A 1	X X X							
2	CLAY(CH) (FILL) - silty - trace of sand - trace of fine gravel - high plasticity - brownish grey to greyish brown - stiff to very stiff			B 2								
3				B 3								

SAMPLE
- UNDISTURBED
- DISTURBED
- NOT RECOVERED

- ⊙ NATURAL WATER CONTENT (w)
- —X LIQUID LIMIT (w_L)
- X— PLASTIC LIMIT (w_p)
- △ UNCONFINED COMPRESSIVE STRENGTH MEASURED WITH POCKET PENETROMETER

SAMPLING METHOD
- A- SPLIT TUBE
- B- SHELBY TUBE
- C- PISTON SAMPLER
- D- CORE BARREL
- E- AUGER
- F- WASH

SUBCONSULTANT : KLOHN LEONOFF LTD.

LOGGED BY: PP

APPROVED: TKH

DATE: MARCH 1986

Alberta ENVIRONMENT

PRIME CONSULTANT
STANLEY ASSOCIATES ENGINEERING LTD.
SUBCONSULTANT
KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 8

SHEET 2 of 7

DEPTH ELEV. (m)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE STATE	SAMPLE No.	PENETRATION TEST (Blows/0.15m) x - STANDARD PENETRATION	UNCONFINED COMPRESSION kPa; PLASTIC LIMIT; WATER CONTENT; LIQUID LIMIT	UNIT WEIGHT (kN/m³)	COHESION (kPa)	ANGLE OF SHEARING RESISTANCE Ø Degrees	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY K (cm/sec)	PARTICLE SIZE (%) CLAY < 0.005mm; SILT 0.005 - 0.080mm; SAND 4.75 - 0.075mm; GRAVEL 76.2 - 4.75mm
5	CLAY(CH) (FILL) - silty - trace of sand - trace of fine gravel - high plasticity - brownish grey to greyish brown - stiff to very stiff			B 4								
6												
7				A 5								
8				B 6				27	19			
9				B 7								

SAMPLE
- UNDISTURBED
- DISTURBED
- NOT RECOVERED

- ⊙ NATURAL WATER CONTENT (w)
- —x LIQUID LIMIT (w_L)
- x— PLASTIC LIMIT (w_P)
- △ q_u UNCONFINED COMPRESSIVE STRENGTH MEASURED WITH POCKET PENETROMETER

SAMPLING METHOD
- A - SPLIT TUBE
- B - SHELBY TUBE
- C - PISTON SAMPLER
- D - CORE BARREL
- E - AUGER
- F - WASH

Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD.
SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 8

SHEET 3 of 7

DEPTH ELEV. (m)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE STATE	SAMPLE No.	PENETRATION TEST (Blows/0.15m) ▪ - STANDARD PENETRATION	UNCONFINED COMPRESSION kPa / PLASTIC LIMIT / WATER CONTENT / LIQUID LIMIT	UNIT WEIGHT (kN/m³)	COHESION (kPa)	ANGLE OF SHEARING RESISTANCE ϕ Deg.	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY K (cm/sec.)	PARTICLE SIZE (%) CLAY < 0.005mm / SILT 0.074 - 0.005mm / SAND 4.76 - 0.074mm / GRAVEL 76.2 - 4.76mm
				7	10 20 30 40	100 200 300 400 / 10 20 30 70 90%						
11	coarse gravel layer from 10.25m - 10.7m			A 8								
12	CLAY(CH) (FILL) - silty - trace of sand - trace of fine gravel - high plasticity - brownish grey to greyish brown - stiff to very stiff			A 9								
13												
14				A 10								
15												
15.50												
1113.2	SAND and GRAVEL - some silt - generally grey - very dense			A 11	72							

SAMPLE
- UNDISTURBED
- DISTURBED
- NOT RECOVERED

- ⊙ NATURAL WATER CONTENT (w)
- —X LIQUID LIMIT (w_L)
- X— PLASTIC LIMIT (w_P)
- △ q_u UNCONFINED COMPRESSIVE STRENGTH MEASURED WITH POCKET PENETROMETER

SAMPLING METHOD
A - SPLIT TUBE
B - SHELBY TUBE
C - PISTON SAMPLER
D - CORE BARREL
E - AUGER
F - WASH

Alberta ENVIRONMENT

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SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 8

SHEET 4 of 7

DEPTH ELEV. (m)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE STATE	SAMPLE No.	PENETRATION TEST (Blows/0.15m) X - STANDARD PENETRATION	UNCONFINED COMPRESSION kPa; PLASTIC LIMIT; WATER CONTENT; LIQUID LIMIT	UNIT WEIGHT kN/m³	COHESION (kPa)	ANGLE OF SHEARING RESISTANCE ϕ Deg.	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY k (cm/sec)	PARTICLE SIZE (%)
				11	12							
17												
				A 12	55 130							
18	SAND and GRAVEL cont'd - some silt - generally grey - very dense											
				A 13								
19												
				A 14								
20												
21												
21.80												
1106.9	CLAYSTONE - generally bluish grey			A 15	50 For 50mm							

SAMPLE
- UNDISTURBED
- DISTURBED
- NOT RECOVERED

- NATURAL WATER CONTENT (w)
- LIQUID LIMIT (w_L)
- PLASTIC LIMIT (w_P)
- UNCONFINED COMPRESSIVE STRENGTH MEASURED WITH POCKET PENETROMETER

SAMPLING METHOD
A - SPLIT TUBE
B - SHELBY TUBE
C - PISTON SAMPLER
D - CORE BARREL
E - AUGER
F - WASH

Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD.

SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 8

SHEET 5 of 7

DEPTH ELEV. (m)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE STATE	SAMPLE No.	PENETRATION TEST (Blows/0.15m) S - STANDARD PENETRATION	UNCONFINED COMPRESSION kPa	PLASTIC LIMIT	WATER CONTENT	LIQUID LIMIT	UNIT WEIGHT kN/m³	COHESION (kPa)	ANGLE OF SHEARING RESISTANCE Φ (Deg)	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY K (cm/sec)	PARTICLE SIZE (%)
	CLAYSTONE cont'd - bluish grey - very silty - very weak														
23	- grey and maroon		A		16 >100 For 50mm	66 Φ									
	- refer to sheet 6														
24															

SAMPLE
- UNDISTURBED
- DISTURBED
- NOT RECOVERED

- ⊙ NATURAL WATER CONTENT (w)
- —x LIQUID LIMIT (w_L)
- x— PLASTIC LIMIT (w_P)
- △ q_u UNCONFINED COMPRESSIVE STRENGTH MEASURED WITH POCKET PENETROMETER

SAMPLING METHOD
A- SPLIT TUBE
B- SHELBY TUBE
C- PISTON SAMPLER
D- CORE BARREL
E- AUGER
F- WASH

Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD.
SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 8
SHEET 6 of 7

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	W.L. & INSTR.	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
23.27	Begin coring at 23.27m		- 23.27-24.79 core loss due to weakness of the rock						
1105.4				0					
	No core recovered over this interval, soft drilling, probably CLAYSTONE			(0)					
24									
24.79									
1103.9				100 (0)				M.C	26.8
25			- 24.95-25.12 very disturbed, sheared						
	CLAYSTONE - silty - light to medium grey - thinly bedded - soft		- 25.26-26.47 some core loss in this interval	20				D 17	
26				(0)					
	dark blackish grey			13 (0)					
26.86				70					
1101.8	SANDSTONE - medium grey - fine to medium grained - very strong - fresh			(0)					
27				93					
	SILTSTONE; medium grey, thinly bedded, fresh		- 27.38-27.60 possible core loss	(0)					
	CLAYSTONE; dark blackish grey, fresh, moderately weak		- 27.69-27.80 sheared	73	1				
	light grey, thickly bedded		- 27.90 irregular joint, 30°, rough	(15)					
28			- 28.12;28.53;28.64 3 planar joints, 60° - 65°, rough, opened by drilling	100					
				(77)	5				
28.80			- 28.80-28.88 possible core loss						
1099.9			28.90-29.75 some shearing in this interval						
29	CLAYSTONE - dark blackish grey - thick bedded - fresh - moderately weak			95					
			- 29.45 irregular joint, 50°, rough	(58)					
			- 29.54 irregular joint, 65°, rough		5				
29.75			- 29.86 irreg. joint, 75° rough						
1099	SILTSTONE - dark grey - fresh - thinly bedded - very strong		- 29.90 irregular joint, 20°, rough						
30									

ABBREVIATIONS:
JTS. - JOINTS
CORE REC. - CORE RECOVERY
R.Q.D. - ROCK QUALITY DESIGNATION
W.L. & INSTR. - WATER LEVEL & INSTRUMENTATION
K. - HYDRAULIC CONDUCTIVITY

Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD.
SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 8
SHEET 7 of 7

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	W.L. & INSTR.	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
	SILTSTONE - dark grey - very strong - thinly bedded - fresh								
30.35			30.35 irregular joint, 15°, tight, rough						
1098.4	CLAYSTONE - dark grey - fresh - weak			100	4				
	SILTSTONE; dark grey, fresh, moderately weak		- 30.65 stepped joint, 65°, rough - 30.80-31.18 many fine joints - 50°, unopened 30.90-31.35 brecciated	(46)					
31									
	SILTSTONE; dark grey, fresh, moderately weak				12				
	dark blackish grey		- 31.64-32.05 brecciated						
32	SILTSTONE; dark grey, fresh moderately strong		- 32.06 planar joint, 15°, smooth - 32.23;32.29 2 planar joints, 80°- 85°, smooth	100 (92)					
	dark grey, thickly bedded, fresh, moderately weak		- 32.46 undulating joint, 15°, tight, polished - 32.67 planar joint, 80°, slickensided		8				
	SILTSTONE; medium grey, fresh, very strong								
33 33.16									
1095.5	END OF HOLE @ 33.16m								
34									

ABBREVIATIONS:
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W.L. & INSTR. - WATER LEVEL & INSTRUMENTATION
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Alberta ENVIRONMENT

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OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 7

SHEET 1 of 7

CONTRACTOR(S)/DRILL RIG(S): A: Chilako Drilling - RE 1050 Auger; B: SDS Drilling - Gardner Denver 1700

RIG No. A DEPTH(m) 12.5 DATE Oct 29/85 HOLE DIAM. 140mm TOP CASING A (El.) 1134.7m

RIG No. B DEP:H(m) 40.0 DATE Nov 16-18/85 CORE DIAM. 76mm TOP CASING B (El.) 1134.8m

LOCATION: SW 12-7-1-W5

COORDINATES: 5489356.3 N
-1397.8 E

INITIAL DIP: VERTICAL

ELEVATIONS: GROUND SURFACE: 1134.2m
ROCK SURFACE: 1120.4m
BOTTOM OF HOLE: 1094.2m

DEPTH ELEV (m)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE STATE	SAMPLE No.	PENETRATION TEST (Blows/0.15m) S - STANDARD PENETRATION	UNCONFINED COMPRESSION kPa; PLASTIC LIMIT; WATER CONTENT; LIQUID LIMIT	UNIT WEIGHT (kN/m³)	COHESION (kPa)	ANGLE OF SHEARING RESISTANCE ϕ°	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY K (m/sec)	PARTICLE SIZE (%)
0.00					10 20 30 40	100 200 300 400; 10 30 50 70 90%						Clay < 0.002 mm; Silt 0.002 - 0.060 mm; Sand 0.06 - 0.2 mm; Gravel 2 - < 76 mm
1134.2	GRAVEL (FILL) - sandy - silty - trace of clay - brown											
1			E	1		⊙						
2			E	2		⊙						
2.20												
1132	CLAY (FILL) - silty - some sand - generally grey		E	2A		⊙						
3			B	3		⊙						
			A	4		⊙						

SAMPLE
- UNDISTURBED
- DISTURBED
- NOT RECOVERED

- ⊙ NATURAL WATER CONTENT (w)
- —X LIQUID LIMIT (w_L)
- X— PLASTIC LIMIT (w_p)
- △ UNCONFINED COMPRESSIVE STRENGTH MEASURED WITH POCKET PENETROMETER

SAMPLING METHOD
- A - SPLIT TUBE
- B - SHELBY TUBE
- C - PISTON SAMPLER
- D - CORE BARREL
- E - AUGER
- F - WASH

SUBCONSULTANT : KLOHN LEONOFF LTD.

LOGGED BY: JZ/IB

APPROVED: TKH

DATE: MARCH 1986

Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD.

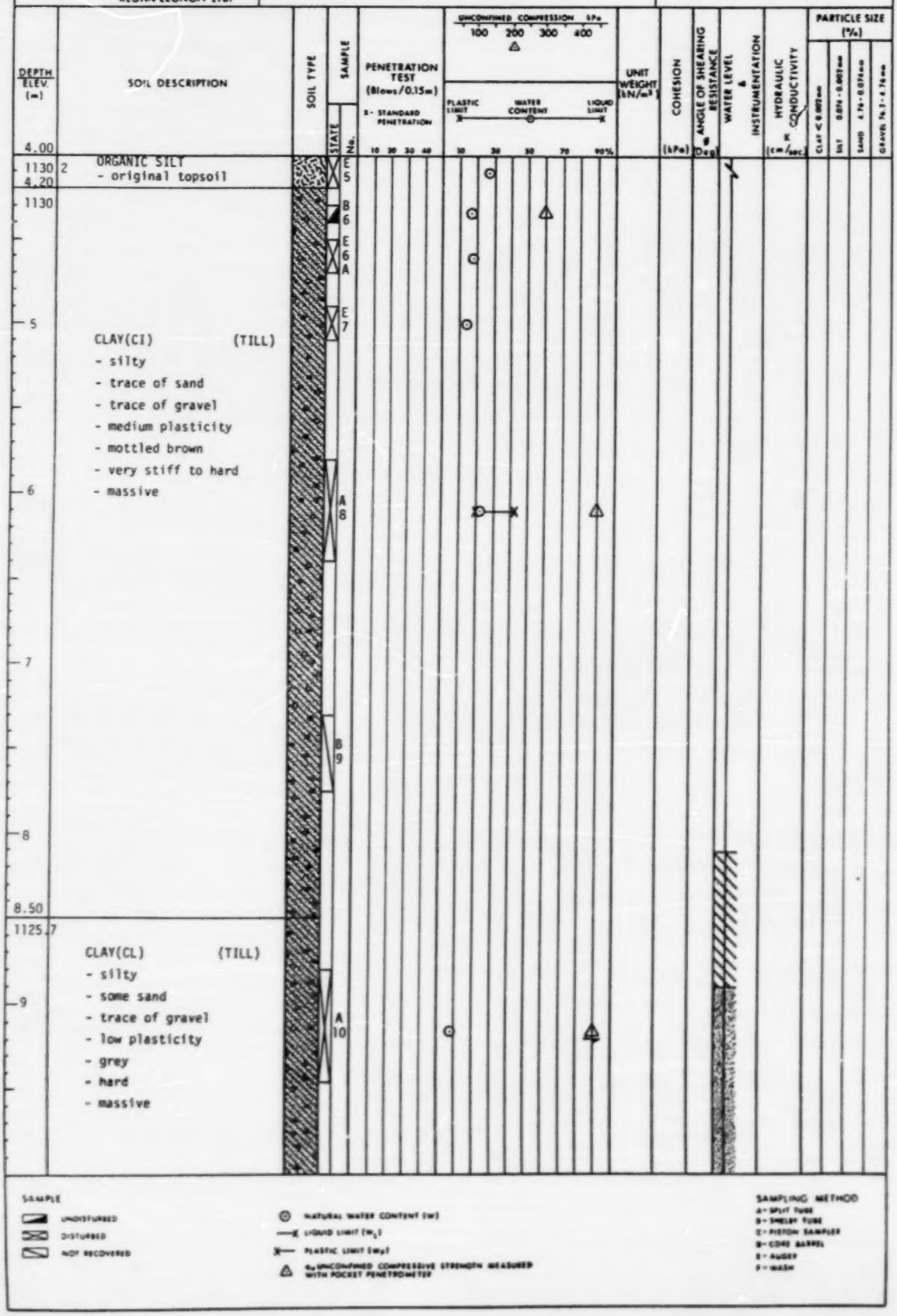
SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 7

SHEET 2 of 7



SAMPLE

- UNDISTURBED
- DISTURBED
- NOT RECOVERED

- ⊙ NATURAL WATER CONTENT (w)
- —⊗— LIQUID LIMIT (w_L)
- ⊢— PLASTIC LIMIT (w_P)
- △ q_u UNCONFINED COMPRESSIVE STRENGTH MEASURED WITH POCKET PENETROMETER

SAMPLING METHOD

- A = SPLIT TUBE
- B = SHELBY TUBE
- C = PISTON SAMPLER
- D = CORE BARREL
- E = AUGER
- F = WASH

Alberta ENVIRONMENT

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SUBCONSULTANT
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OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 7

SHEET 3 of 7

DEPTH ELEV (m)	SOIL DESCRIPTION	SOIL TYPE	SAMPLE STATE	SAMPLE No.	PENETRATION TEST (Blows/0.15m) X - STANDARD PENETRATION	UNCONFINED COMPRESSION kPa	PLASTIC LIMIT	WATER CONTENT	LIQUID LIMIT	UNIT WEIGHT kN/m³	COHESION (kPa)	ANGLE OF SHEARING RESISTANCE ϕ Deg.	WATER LEVEL & INSTRUMENTATION	HYDRAULIC CONDUCTIVITY K (cm/sec)	PARTICLE SIZE (%) CLAY < 0.002mm	SILT 0.074 - 0.002mm	SAND 4.76 - 0.074mm	GRAVEL 76.2 - 4.76mm
					10 20 30 40	100 200 300 400	10	20	30	40	95%									
			A	11	50 For 108mm															
11	CLAY(CL) (TILL) - silty - some sand - trace of gravel - low plasticity - grey - hard - massive													Pz 4 Dry Dec 17/85 Dry Jan 9/86						
12			A	12																
			A	13	100 For 76mm															
13																				
13.80 1120.4	CLAYSTONE - refer to sheet 4																			

SAMPLE
- UNDISTURBED
- DISTURBED
- NOT RECOVERED

- NATURAL WATER CONTENT (w)
- LIQUID LIMIT (w_L)
- PLASTIC LIMIT (w_P)
- q_u UNCONFINED COMPRESSIVE STRENGTH MEASURED WITH POCKET PENETROMETER

SAMPLING METHOD
A - SPLIT TUBE
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Alberta ENVIRONMENT

PRIME CONSULTANT: STANLEY ASSOCIATES ENGINEERING LTD.
SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 7
SHEET 4 of 7

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	WL & INSTR	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
13.80	BEDROCK								
1120.4									
14	CLAYSTONE								
14.50	Begin coring at 14.50m								
1119.7			- 14.50-15.00 core loss Core probably slipped through the core catcher and was ground up on the next run.	0 (0)					
15	CLAYSTONE - dark greenish grey - thickly bedded - moderately to highly weathered - extremely weak		- 15.55-16.00 core loss, probably slippage past core catcher	55 (47)	0			D 14	
16			- 16.33 planar shear surface at 70° TCA, slickensided, moderately narrow with breccia infilling	92 (80)	4				
17	SILTSTONE; medium greenish grey, thinly bedded, dip 5°, moderately weathered, strong		- 16.90 planar contact at 85° TCA		1				
18	CLAYSTONE; bright dark greenish grey, thickly bedded, moderately weathered, moderately weak		- 17.70 planar shear surface at 80° TCA, breccia infilling (10mm)						
			- 18.06-18.51 drilling induced tight fractures at 85° - 90° TCA	86 (64)	1			D 15	
19			- 18.66 planar shear surface at 90° TCA, moderately narrow with clay gouge and breccia infilling						
	calcrete nodules, 3 - 4 cm diameter		- 19.63 clay infilled planar joint at 85° TCA		1				
20			- 19.72-20.00 core loss, probably slippage past core catcher						

ABBREVIATIONS:
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Alberta ENVIRONMENT

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SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 7
SHEET 5 of 7

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	W.L. & INSTR	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
	CLAYSTONE - dark greenish grey - thickly bedded - moderately weathered - moderately weak		- 20.39-20.80 joint set (3) at 35° - 40° TCA, tight, planar, smooth fractures	90 (69)	4				
21	highly weathered, very weak		- 21.00-21.90 sheared zone, many high angle, discontinuous slickensides		0			D 16	
22			- 22.12-22.25 clay gouge, very stiff						
22.37			- 22.33-22.37 planar shear surface at 75° TCA, slickensides with clay gouge infilling					D 17	
1111.8	SILTSTONE - dark to medium grey - thickly bedded - moderately weathered - very weak			100 (73)	3				
23					2				
23.82			- 23.82-23.98 shear zone, planar shear at 80° TCA, claystone breccia and clay gouge infilling						
1110.4	CLAYSTONE - dark greenish grey - very thickly bedded - moderately weathered - weak to very weak			100 (85)	0			M.C 8.8 L.L 32.2 P.L 21.2 P.I 11.0 Unit wt 22.91	
24									
25	highly weathered, very weak		- 24.80-25.30 shear zone, many high angle, discontinuous slickensides		2			D 18	
26			- 25.65-26.01 planar joint set (3) at 80° TCA, smooth, some with trace clay infilling	64 (60)	1				
	trace fossils								
27									

ABBREVIATIONS:
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Alberta ENVIRONMENT

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SUBCONSULTANT: KLOHN LEONOFF LTD.

OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 7
SHEET 6 of 7

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	W.L. & INSTR.	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
	CLAYSTONE - dark greenish grey - very thickly bedded - moderately weathered - weak to very weak		- 27.13-28.00 core loss, probably slippage past core catcher, possible clay gouge as soft, plastic, light grey clay stuck to bottom of recovered core run	64 (60)	-				
28.00 1106.2 28.18	SANDSTONE - fine grained - medium grey - very strong		- 28.18 contact at 80° TCA					D 19	
1106	SILTSTONE - medium grey - medium bedded - slightly weathered - strong		- 28.35-28.50 2 planar joints at 65° TCA	100 (100)	4				
29.05 1105.2 29.56	SANDSTONE - medium grained - light grey - moderately weathered - salt and pepper texture - thinly bedded - very strong - dip 10°		- 29.05 contact at 75° TCA		4				
1104.6 30	SILTSTONE - dark grey to black - moderately weathered - strong		- 29.56 contact at 75°- 80° TCA - 29.80 20mm thick seam of very weak claystone	84 (80)					
30.30 1103.9	SANDSTONE - light grey - thinly bedded - dip 5° - fine grained - slightly weathered - very strong			97 (91)	1				
31			- 31.76 20mm thick seam of very weak claystone		5				
32	CLAYSTONE; dark grey, medium bedded, moderately weathered, moderately weak		- 32.20 planar contact at 85° TCA		6				
	medium grained, salt and pepper texture		- 32.60 planar contact at 80° TCA	95.2					
	CLAYSTONE; moderately weathered, moderately weak		- 32.82 planar contact at 85° TCA	(89)					
33	coarse grained, salt and pepper texture, medium bedded, dip 10°, very strong				0				
34	medium grained grading to fine grained								

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OLDMAN RIVER DAM

DRILLHOLE LOG

HOLE No. 85 - 7
SHEET 7 of 7

DEPTH ELEV (m)	ROCK DESCRIPTION	ROCK TYPE	DISCONTINUITY CHARACTERISTICS	CORE REC. (R.Q.D.) (%)	JTS per m	W.L. & INSTR	K (cm/s)	TEST SAMPLE & TYPE	TEST RESULTS
	SANDSTONE cont'd			95.2 (89)					
34.30			- 34.30-36.30 core loss of 0.70m. Probable washing of clay gouge material 34.50-35.50 water loss =50% circulation						
1099.9	CLAYSTONE - dark green (bright) - moderately to highly weathered - very weak				5				
	& CLAY GOUGE - dark olive green - very stiff - plastic		34.30-35.50 fault zone, sheared claystone showing slickensides in two directions: 1) approximately 80° TCA 2) discontinuous high angle (ie. 10°- 20° TCA) as well as claystone breccia and very stiff clay gouge	65 (16)				D 20	
35									
	moderately weathered, very weak, trace of slickensides		- 35.54-35.81 many fractures at 80°- 90° TCA, many have a trace of clay infilling		14			D 22	
	SILTSTONE SANDSTONE; strong, slightly weathered		- 35.84-35.93 shear zone, breccia infill						
36	SILTSTONE CLAYSTONE; very weak								
36.24			- 36.24 contact at 90° TCA						
1098	SANDSTONE - light grey - salt and pepper texture - medium to coarse grained - thinly bedded - dip 5° - moderately weathered - strong		- 36.30-36.35 claystone breccia and clay gouge - 36.60-37.22 drilling induced fractures (20) at 85°- 90° TCA	100	5			D 23	
37				(45)					
	SILTSTONE		- 37.34 contact at 90° TCA						
37.48			- 37.48-37.80 shear zone, claystone slickensided in two directions: 1) approximately 80°- 85°TCA 2) discontinuous high angle		16				
1096.7	CLAYSTONE - dark green - moderately weathered - very weak							D 24	
	& CLAY GOUGE - stiff								
38									
38.20									
1096	SANDSTONE - medium grey - medium bedded - dip 20° - medium grained - slightly weathered - very strong			100 (100)		Pz B			
39	light grey, coarse grained, salt and pepper texture								
	medium grey, medium grained								
39.75			- 39.75 contact at 75° TCA						
1094.5 40.00	CLAYSTONE - dark grey - moderately weak								
1094.2	END OF HOLE @ 40.00m								

ABBREVIATIONS:
JTS - JOINTS
CORE REC. - CORE RECOVERY
RQD - ROCK QUALITY DESIGNATION
W.L. & INSTR. - WATER LEVEL & INSTRUMENTATION
K. - HYDRAULIC CONDUCTIVITY

MAPS
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CARTES
OMISES